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Attractiveness of Pine-Tar Oil in Baits for Codling Moth Control

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In a series of tests of baits for control of the codling moth *Carpocapsa pomonella* (L.), the addition of pine-tar oil[1] and certain other chemicals to the fermenting molasses bait had given promising results (Van Leeuwen 1943). To determine the most effective materials for baits and the most efficient method of utilizing the baits, various experiments were made in apple orchards near Yakima, Wash., during the years 1934–38. This paper includes the results of a number of preliminary tests of pine-tar oil, together with results obtained in a large-scale experiment in orchards.

PROCEDURE.—The method used in most of the tests was to compare the number of moths caught with a standard bait, composed of 1 part of molasses, 10 parts of water, and 1 cake of yeast to every 10 gallons of bait, with a similar bait to which pine-tar oil had been added. Enameled stew pans 7 inches in diameter and 4 inches deep, each containing 1 quart of bait, were placed in the upper center branches of the apple tree. They were suspended on 18-inch cross arms nailed to pieces of lumber 3.5 inches wide, 0.75 inch thick, and long enough to reach the upper third of the tree. Each piece of lumber, with its cross arm, or "station," held two pans, one containing the standard molasses bait and the other the test bait. Usually, only one cross arm was used in a tree. Unless otherwise mentioned, each bait was replicated two to four times. The baits were examined about every other day, at which time water was added to replace that lost by evaporation.

[1] According to the manufacturer's statement, the specifications of pine-tar oil used were as follows: Specific gravity, 1.020 at 15.5° C.; boiling range, as determined by A.S.T.M. Method D20–30—minimum initial boiling point 95° C., at least 80 per cent distilling over, at, or below 360° C.; acid Nos. 20 to 40; moisture, 2 per cent maximum; should be soluble in all pine and refined coal-tar distillates and in alcohol and ethyl ether.

COMPARATIVE TESTS OF PINE-TAR OIL WITH STANDARD BAIT.—The most efficient way of using pine-tar oil in baits had to be determined before it was possible to test its value as a control measure for the codling moth.

Emulsified in Water.—To determine whether pine-tar oil was attractive, an emulsion, made by dissolving 5 gm. of saponin in 80 ml. of water and adding 20 ml. of pine-tar oil, was tested. A few moths were attracted to these pine-tar-oil baits, but not as many as came to the standard baits (Table 1).

Table 1.—Attractiveness to codling moths of pine-tar oil emulsified in water.

PINE-TAR OIL USED PER QUART OF WATER (ML.)	NUMBER OF MOTHS ATTRACTED BY—		DECREASE IN CATCH BELOW STANDARD BAIT
	Standard Bait	Pine-Tar Oil	
1.5	88	55	38%
3	88	45	49
4.5	65	59	9
6	74	67	9
15	150	57	62

Mixed with Highly Refined White Oil.—If pine-tar oil mixed with an odorless oil were attractive to codling moths, it would have many advantages over the standard bait. After its discovery as an attractant, pine-tar oil was mixed with a highly refined white oil, and dilutions of this mixture ranging from 1.5 to 30 ml. per quart were tested, standard bait being used as a check. Less than 10 per cent as many moths were caught with the mixture as with the standard bait.

Used in an Evaporation Cup.—To determine the attractiveness of pine-tar oil used with the standard bait, 8 tests were made during different periods. The pine-

tar oil was placed in a small vial (surface area 1.3 sq. cm.) and floated on the standard bait by means of a small flat cork through which a hole had been drilled to accommodate the vial. This vial, or "evaporation cup," was developed by Peterson (1926). The standard bait with the vial of pine-tar oil was compared with a standard bait without pine-tar oil. The results show that in every test the pine-tar oil increased the catch of moths, the increase ranging from 93 to 209 per cent.

Used Near Standard Bait.—In many of the experiments pine-tar oil was added to standard bait, for comparison with standard bait used alone. It was believed that the increase in catch was due to the presence of the pine-tar oil, but the results of the experiments summarized in table 2 indicate that the increase was due to a combination of the standard bait and pine-tar oil. In two tests of another series a standard bait was compared with water plus a vial (surface area 1.3 sq. cm.) of pine-tar oil, and in two other tests water alone was compared with water plus a similar vial of pine-tar oil. The water with pine-tar oil captured more moths than did the standard bait. In the tests of the water and pine-tar-oil combination, as compared with water alone, few moths were attracted to either. The total numbers of moths attracted to the water and pine-tar-oil bait with a standard bait near by were 982 and 244, as compared with 281 and 109, respectively, caught by water and pine-tar oil without the presence of standard bait. The pine-tar oil was therefore definitely attractive, but it captured many more moths when it was placed close to a standard bait.

Table 2.—Attractiveness of water, water and pine-tar oil, and standard bait to codling moths.

Period	Number of Moths Attracted to—			Per Cent Increase Attributed to Pine-Tar Oil
	Standard Bait	Water	Water and Pine-Tar Oil	
June 9 to July 2	697	—	982	41
	—	44	281	539
August 7 to 13	203	—	244	20
	—	26	109	319

Used in Separated Areas.—A test was made to determine whether the standard bait with a vial of pine-tar oil (surface area 1.3 sq. cm.) was more attractive in a given area of orchard than was the standard bait without the oil. Two widely separated blocks of trees within an orchard were selected. Nine traps of each bait were used, alternating the baits in each block approximately every other day, over a period of 21 days. A total of 2063 moths were taken with the standard bait, plus pine-tar oil, as compared with 760 taken with the standard bait alone. Therefore the presence of the pine-tar oil increased the attractiveness 171 per cent. The results of this test also nullified the suggestion that all the moths would have been caught by the standard bait had not the more attractive bait been present.

Used in a Dispenser.—To determine whether the odor from a large volume of pine-tar oil would attract many moths, a dispenser consisting of two pans, each 10 inches in diameter and 5 inches deep, was used. One pan was placed 12 inches below the other. Connecting the two were 5 wicks, each 0.25 inch in diameter and 1 foot long and composed of 12 strands running from holes in the upper pan to hooks on the bottom of the lower pan. Pine-tar oil was placed in the upper pan. The five wicks permitted the oil to drain slowly from the upper to the lower pan. This dispenser was hung in the upper part of a tree, with a standard bait suspended about 4 feet below it. With the tree containing the dispenser as a center, six other standard baits were placed in trees surrounding it, but two rows distant. Two plats of this type were selected, the dispenser being alternated from plat to plat. In every observation except one (May 24) the baits in the plat of trees containing the dispenser attracted the most moths. The dispenser increased the catch of moths from 937 to 1495, or 59.5 per cent.

Emulsified in Standard Bait.—None of the mixtures of pine-tar-oil emulsion and standard bait were permanently stable. Some remained stable for several days, and then broke, with oil floating on the surface. To determine the best quantity of pine-tar oil to mix with the standard bait, three series of experiments were made. Owing probably to the fact that the pine-tar oil separated in the bait, the results of the tests (Table 3) were variable, but the data show that in each series the presence of pine-tar oil increased the catch of moths.

Effect of Semiweekly Additions.—To

compensate for the evaporation that takes place in a liquid bait upon exposure, three series of tests were made by adding various quantities of pine-tar oil emulsion to a standard bait at semiweekly intervals. In each series the results were compared with those of a standard bait to which no additional emulsion was supplied. In the first two series, the standard bait originally contained 0.5 ml. of pine-tar-oil emulsion per quart. The semiweekly additions ranged from 0.125 to 0.5 ml. of pine-tar-oil emulsion. In the third series

Table 3.—Attractiveness of standard bait plus emulsified pine-tar oil to codling moths, in comparison with standard bait alone.

Period of Test	Emulsified Pine-Tar Oil per Quart of Standard Bait (ml.)	Number of Moths Caught in Standard Bait— Alone	With Pine-Tar Oil	Per Cent Increase Attributed to Pine-Tar Oil
		First Series		
July 3 to 23	0.33	103	269	161
	.25	81	221	173
	.5	17	84	394
	.75	50	211	322
	1.0	80	170	113
		Second Series		
June 3 to 13	.25	15	39	160
	.5	19	44	132
	.75	36	60	67
	1.0	34	66	94
		Third Series		
May 22 to June 7	.2	119	279	134
	.4	103	274	166
	.6	89	161	81
	.8	91	247	171
	1.0	85	280	229
		Fourth Series		
June 11 to 18	.2	45	77	71
	.4	48	103	115
	.6	46	140	204
	.8	34	80	135
	1.0	29	82	183

0.75 ml. of pine-tar-oil emulsion per quart of standard bait was used originally and additions ranging from 0.375 to 0.75 ml. per quart of bait were supplied later. As shown in table 4, all additions of pine-tar-oil increased the catch of moths. In the first two series of tests, the baits that received additional quantities attracted more moths than did the bait not thus supplemented. However, in the third series the data indicate that too much oil was present for maximum attraction, and the standard bait with no additions of pine-tar oil had the highest per cent increase in catch.

Attractiveness of a Vial of Pine-tar Oil as Compared with Emulsion.—The method used in the tests described on page 7 was followed, to determine whether pine-tar oil in a vial having a surface area of 1.3 sq. cm., suspended over 1 quart of stand-

Table 4.—Attractiveness of standard bait as affected by semiweekly additions of pine-tar-oil emulsion.

Quantity of Pine-Tar Emulsion per Quart of (ml.)	Semiweekly Additions of Emulsion (ml.)	Number of Moths Attracted to— Standard Bait	Test Bait	Per Cent Increase Attributed to Pine-Tar Oil
		First Series		
0.5	0.125	345	987	186
	.25	165	671	307
	.375	157	597	280
	.5	264	802	204
	.0	352	682	94
		Second Series		
.5	.125	93	308	231
	.25	68	259	281
	.375	91	387	324
	.5	86	453	427
	.0	43	103	140
		Third Series		
.75	.375	100	215	115
	.5	112	197	76
	.625	143	260	82
	.75	199	423	113
	.0	85	221	160

ard bait, was more attractive than 0.5 ml. of pine-tar oil emulsified in 1 quart of standard bait. The experiment was conducted in two plats of trees during the period August 15 to 28, 1934, and the baits were interchanged daily. The bait with the vial of pine-tar oil captured 43 per cent more moths than did the bait containing the emulsified pine-tar oil.

When Used in the Same Tree.—In an experiment somewhat similar to the one just described, four stations in four trees were used. On the left side of the cross arm of these stations standard bait containing 0.5 ml. of emulsified pine-tar oil was used, while the bait on the right side was standard accompanied by a vial (surface area 1.3 sq. cm.) of a pine-tar oil. The experiment covered a period of 12 days, and the baits were interchanged every other day. The increase in favor of the bait with the vial of pine-tar oil was 29.7 per cent.

ATTRACTIVENESS OF INCREASED QUANTITIES OF PINE-TAR OIL.—The results of previous experiments indicated that the best method of dispersing pine-tar odor was by using vials for holding the oil. A test was therefore conducted with different-sized vials, to determine the surface area required to attract the largest number of moths. The volume of the vials varied with their surface area, which ranged from 0.4 to 25.8 sq. cm. All vials were floated on the surface of the bait.

The most effective surface area was indicated to be 1.3 sq. cm., and the increase in catch, as compared with stand-

ard bait alone, was 105 per cent. As the surface area of the vial was increased beyond 1.3 sq. cm., the per cent increase of moths decreased (Table 5.) The number of moths caught with the test bait decreased from 230 to 179, with one exception, while the catch with standard bait increased from 134 to 265. This fact indicates that the larger vials of oil may have released too strong an odor, thus preventing the moths from approaching close enough to be caught, yet enticing them within the range of the odors emanating from the standard bait.

Table 5.—Attractiveness of various quantities of pine-tar oil in vials.

Surface Area of Vials (sq. cm.)	Number of Moths Caught by		Per Cent Catch, as Compared with Standard Bait
	Standard Bait	Test Bait	
0.4	206	337	+ 64
1.3	153	314	+105
2.3	134	230	+ 72
11.4	170	187	+ 10
18.2	222	165	− 26
25.8	265	179	− 32

To determine whether the increased quantity of pine-tar oil was attracting larger numbers of moths, the baits were arranged as follows: Wooden platforms were placed in the upper third of unsprayed trees, and on each was placed a pan containing standard bait and eight similar pans containing water and 1 per cent of saponin, a non-attractive material. Suspended above the center of the standard-bait container was a vial of pine-tar oil. Vials of four different sizes were used, one to each pan, and each test was run in duplicate. Two platforms on which were placed pans containing molasses bait without pine-tar oil were also used.

The nine pans on each platform were arranged as follows: In the center of the platform was placed the pan containing the standard bait. Four pans of water and saponin were placed next to the center pan, and equally spaced around it. The second set of four pans having pine oil in vials was placed 8 inches from the center pan and next to the first set, thus forming two broken circles of pans about the center pan. The test covered a period of 51 days, and observations were made every other day (Table 6.)

Each quantity of pine-tar oil used increased the catch of moths, as compared with the standard bait alone. As the quantity of pine-tar oil was increased, with one exception, the per cent of moths caught in the two circles of traps surrounding the bait was also increased, therefore a slight repelling or less favorable reaction of the moths to the bait was indicated.

Table 6.—Reaction of codling moths to increased quantities of pine-tar oil in vials.

Surface Area of Vial (sq. cm.)	Total Number of Moths Caught	Per Cent of Moths Caught by—		
		Standard Bait	Water-saponin pans	
			Inner Circle	Outer Circle
0	278	25	42	33
1.3	1821	55	31	14
2.3	2540	46	35	19
11.4	2229	43	39	18
18.2	2659	32	42	26

FRACTIONS OF PINE-TAR OIL.—It was thought that a certain definite chemical in the pine-tar oil might be responsible for the attraction of the codling moths. Tests were therefore made with a few fractions of pine-tar oil. These fractions were made by R. H. Robinson, chemist, of the Oregon Agricultural College. They were as follows:

(1) Refractionated oil by direct distillation from pine-tar oil, after steam distillation, sp. gr. 1.035; boiling point 100°–150° C.
(2) Refractionated oil by direct distillation, after steam distillation from pine-tar oil, sp. gr. 1.035; boiling point 150°–170° C.
(3) Refractionated oil by direct distillation, after steam distillation from pine-tar oil, sp. gr. 1.035; boiling point 170°–180° C.
(4) Refractionated oil by direct distillation, after steam distillation from pine-tar oil, sp. gr. 1.035; boiling point 180°–200° C.
(5) Refractionated oil by direct distillation, after steam distillation from pine-tar oil, sp. gr. 1.035; boiling point 200° C.
(6) Residue from steam distillation and subsequent fractional distillation. Probably considerable decomposition material. Not a definite product for a series of runs.
(7) Steam-volatile fraction, redistilled from pine-tar oil having sp. gr. 1.035.
(8) Steam-volatile fraction, redistilled from pine-tar oil having sp. gr. 1.025.

Each fraction of pine-tar oil was superior to standard bait (Table 7). Except for fraction 5, the per cent increase over standard bait was gradual for the concentration used. Three of the fractions—namely 4, 6, and 8—were more attractive

Table 7.—Attractiveness of various fractions of pine-tar oil to codling moths.

Fraction No.	Number of Moths Caught in Bait		Per Cent Increase Over Standard Bait
	Standard	Test	
1	160	261	63
2	301	579	92
3	256	533	108
4	228	627	175
5	154	374	143
6	153	432	182
7	346	681	97
8	309	838	171
Unfractionated oil, sp. gr. 1.035	238	606	155

than the oil from which the fractions were made.

COMBINATION BAITS.—Little has been learned concerning the nature of the attractiveness of a fermenting-molasses bait. It may be due to a mixture of fermenting substances produced by growing yeast cells. Molasses or yeast by itself is not attractive. Over a period of 5 years, numerous chemicals have been tested as possible attractants for the codling moth. When used alone, none of these materials has proved to be strongly attractive to the codling moth, but many of them, when mixed with fermenting molasses bait, have increased the catch of moths over the standard molasses bait. The results of these tests suggest that the attraction of moths may be due to a mixture of odors rather than to the odor from any one material. It is also believed that the natural odors emanating from apple trees attract the codling moth.

It is difficult to make a satisfactory experiment with a bait composed of several chemicals. The study is complicated by the many possible blends of odors and by other factors. The experiments made with combination baits included pine-tar oil and molasses, to which were added valeric acid and nicotine sulfate (40 per cent nicotine) in different amounts. Pine-tar oil, being insoluble in the bait, was used in a 1-ounce-bottle dispenser; valeric acid and nicotine sulfate, being soluble in the bait, were added directly to it. The quantities of valeric acid and nicotine sulfate used in the tests ranged from 0.5 to 3 ml. per quart of bait, but the quantity of pine-tar oil was not varied. The results of the tests, as compared with a standard bait, are given in table 8. They

Table 8.—Attractiveness of combination baits to codling moths.

Pine-Tar-Oil-Molasses Bait With—		Number of Moths Caught in Bait		Per Cent Increase over Standard Bait
Valeric Acid (ml.)	Nicotine sulfate (ml.)	Standard	Test	
0.5	0.5	1365	3498	156
1.0	.5	1878	5103	72
.5	1.0	1789	6017	236
1.0	1.0	1871	4133	121
2.0	2.0	1826	4523	146
3.0	3.0	2327	4585	97

indicate that the best combination consists of 0.5 ml. of valeric acid, 1 ml. of nicotine sulfate (40 per cent nicotine), and 1 ounce of pine-tar oil in a dispenser.

To determine the efficiency of 3 baits with pine-tar oil as one of the ingredients, the following methods were used:

(1) Baits were replicated from 4 to 20 times, one bait being used to a tree.
(2) Baits were replicated from 8 to 10 times and were divided into groups, each of which contained one bait of each kind. The groups were distributed in the orchard.
(3) Each bait was replicated 5 times, using one bait to a tree. Baits were distributed in two adjacent rows of trees and were shifted in clockwise direction, from tree to tree, about twice a week. This method was adopted from the unpublished notes of L. F. Steiner.
(4) Each bait was replicated from 4 to 5 times, using one bait to a tree, and the results were compared with a standard bait located about 20 inches distant.

The baits tested were:

(A) Standard bait 1 quart, valeric acid 0.5 ml., and pine-tar oil 1 ounce, in a bottle dispenser.
(B) Standard bait 1 quart, nicotine sulfate 1 ml. and pine-tar oil 1 ounce, in a bottle dispenser.
(C) Standard bait 1 quart, valeric acid 0.5 ml. nicotine sulfate 1 ml., and pine-tar oil 1 ounce, in a bottle dispenser.

In 1936 bait C was superior to baits A and B in all three methods tested, and bait B was superior to bait A. In 1937 and 1938 bait B, with one exception, was superior to bait C. This indicated that valeric acid did not add materially to the efficiency of the bait. Variations from year to year resulted in the percentage increase in catch of moths. These differences were, no doubt, due to weather conditions, to the natural variation in the responsiveness of the insect to its physiological condition, and to other factors. The outstanding result from the 3 years' tests is that, with one exception, all experimental baits proved superior to the

standard bait, regardless of the method used (Table 9).

MOLASSES AND PINE-TAR-OIL BAIT.—The fact that large numbers of codling moths were caught with molasses bait when pine-tar oil was used with it, indicated that many might be destroyed if such baits were used on a larger scale. To determine the effect on the codling moth infestation, baits, which had been improved from time to time, were used as a supplementary control measure. The baited areas were compared with similar unbaited areas for four seasons.

Table 9.—Efficiency of combination baits as tested by four methods.

Test Period	Method No.	Per Cent Increase of Catch by Baits		
		A	B	C
May 12 to Sept. 21, 1936	1	52	115	150
	2	88	94	139
	4	186	260	327
July 23 to Sept. 5, 1937	1	—	665	332
	2	—	108	68
	4	—	103	312
July 1 to Sept. 9, 1938	1	—	186	−26[1]
	3	—	206	11
	4	—	354	61

[1] Decrease.

Methods.—During the first 2 years of the tests, 5-acre orchard plots were utilized, but, since these plots appeared too small because of the migration of moths from adjacent unbaited orchards, their size was increased to 10 acres during the last 2 years. Each plot was arranged in the form of a square. All baited plots were surrounded by apple trees, except two, one of which (Varker orchard) had open ground on one side, with the nearest orchard about 500 feet away, and the other (Siepman orchard) had open ground on one side, with the nearest apple trees 1500 feet distant.

A few trees in the central area of each baited block were used for testing several promising baits. In the remainder of the area the standard bait was improved from time to time by adding the following to each quart:

1935—1 ml. of emulsified pine-tar oil.
1936—A dispenser for pine-tar oil.
1937—0.5 ml. of valeric acid, 1 ml. of nicotine sulfate (40 per cent nicotine), and a dispenser for pine-tar oil.
1938—1 ml. of nicotine sulfate (40 per cent nicotine) and a dispenser for pine-tar oil.

The dispenser for vaporizing pine-tar oil consisted of a 1-ounce glass bottle with a small galvanized iron disk 19 mm. in diameter attached to its neck, to prevent rain from entering the mouth. The bottle was filled with oil and its mouth was placed in the middle of the bait and 1 inch above the surface. It was held in place with wire fastened to the sides of the pot. A pot containing about 1 quart of the bait was placed in the upper third of each tree. These pots were examined about every third or fourth day throughout the season, and water was added when necessary to maintain their original volume. All moths were removed and the number in representative trees were counted. About every fourth week, the old bait was discarded and fresh bait supplied. The total and average numbers of moths taken from the baits in count trees, the total numbers of trees, and the calculated numbers of moths destroyed in each baited area are given in table 10.

Table 10.—Number of codling moths destroyed by baits.

Year	Count Trees	Moths per Trees	Moths Destroyed in Count Trees	Trees in Baited Area	Moths Destroyed in Baited Area (Calculated)
1935	32	433	13,856	251	108,683
1936	84	263	22,092	251	66,013
1936	87	272	23,664	262	71,264
1937	68	75	5,100	442	33,150
1938	36	352	12,672	411	144,672

Effect on Moth Population.—From the numbers of moths captured with the baits in evenly distributed count trees, it was established that the greatest numbers were caught in the baits on the outer edge of the baited area. There was a gradual decrease in the numbers taken from the baits nearer the center, indicating that many moths drifted or migrated from unbaited trees to the baited areas. The extent of this movement is shown in table 11.

Table 11.—Distribution of moth populations in orchards as indicated by bait catches.

Location of Bait from Outer Edge of Orchard	Per Cent of Total Moths Caught				
	1935, Gilbert Orchard	1936, Gilbert Orchard	1936, Siepman Orchard	1937, Varker Orchard	1938, Bjorge Orchard
On outer edge	43.7	45.8	49.9	62.3	40.9
Second group	27.0	23.8	18.2	17.1	22.9
Third group	14.6	12.6	11.9	10.9	23.3
Fourth group	14.6	9.8	9.8	9.7	12.9
Fifth group	—	8.0	10.2	—	—

In two orchards (Varker and Sipeman) baits in the outside rows adjacent to open ground caught fewer moths than did the baits on the edges next to unbaited trees. In the Varker orchard the baits on the edge next to a frontage of 1500 feet of open ground averaged 98 moths per bait, whereas the baits in the other outside rows, each of which was adjacent to unbaited trees, averaged 159, 261, and 280 moths. In the Siepman orchard the baits next to open ground and 500 feet from unbaited trees averaged 308 moths per bait, whereas the baits adjacent to unbaited trees averaged 633, 546, and 639 moths.

Effect on Fruit Infestation.—To determine the effect on fruit infestation of killing a large number of moths, one count tree to each 8 to 10 in the baited and unbaited areas was selected and the apples were examined for worm injury at harvesttime. The results of the 4 years' tests in the 5 orchards are given in table 12.

Table 12.—Condition of apples examined in baited and unbaited experimental plats.

Orchard and Year	Area	Variety	Baited		Not Baited	
			Wormy (Per cent)	Stung (Per cent)	Wormy (Per cent)	Stung (Per cent)
	Acres					
1935						
Gilbert	5	Winesap	15.0	30.7	11.7	30.4
1936						
Gilbert	5	Jonathan	7.2	18.2	8.2	20.2
		Winesap	2.6	18.6	1.9	13.7
Siepman	5	Jonathan	15.9	20.9	17.6	20.4
		Winesap	3.5	19.5	3.7	23.9
1937						
Varker	10	Jonathan	10.1	17.1	19.6	40.7
		Delicious	6.7	24.0	12.6	37.0
		Winesap	2.1	21.9	4.7	33.1
1938						
Bjorge	10	Jonathan	29.9	43.4	34.5	42.6
		Delicious	18.2	31.4	12.5	27.1
		Winesap	3.9	25.1	5.6	25.7
		Rome	25.8	44.6	27.8	47.5

A comparison of infestation in the baited and unbaited areas shows that, with one exception, there was very little difference between the two. In the orchard used in 1937 the baited area was much freer of wormy fruit than was the unbaited orchard. Considering, however, the amount of time required to service and maintain bait traps, the results do not indicate that the baits tested have practical value.

It was concluded that the apparent failure of the baits to reduce the codling moth injury was not due altogether to the inefficiency of the baits, but was partly the result of a movement of moths from unbaited areas. There was a gradual decrease in numbers of moths caught toward the center of the baited area, indicating that many moths were moving in from the outside, presumably because of the attraction of the baits and prevalent drifting or migrating more or less over the entire baited section of the orchard. However, more of them were captured by the first baits encountered than by others. As a result of moth flight into the baited areas, the moth population in the check area was reduced and the numbers in the baited areas were increased. Since not all moths attracted are caught, moths coming from the outside complicated control of the baits, making it difficult to demonstrate the value of bait as s supplementary control measure for codling moth.

SUMMARY.—The attractiveness of pine-tar oil to the codling moth, *Carpocapsa pomonella* (L.), was determined under varied conditions in apple orchards near Yakima, Wash. This investigation included a study of the attractive influence of pine-tar oil when used with a standard bait composed of molasses, yeast, and water. An experiment was also made with pine-tar-oil baits in orchards, to determine their value as supplementary control measures for the codling moth.

Of the various methods used, the most practical way of utilizing pine-tar oil in baits was to keep it in a separate container placed near the bait.

The most effective codling moth bait consisted of 1 quart of standard bait, 0.5 ml. of valeric acid, 1 ml. of nicotine sulfate (40 per cent nicotine), and 1 ounce of pine-tar oil in a bottle dispenser.

Thousands of codling moths were captured in baited areas in orchards, but observations on moth injury to the fruit did not indicate any worthwhile control over adjacent unbaited areas.

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Factors Affecting Use and Phytotoxicity of DDT and Other Insecticides for Squash Borer Control[1]

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In formulating a program for the control of the squash borer, *Melittia cucurbitae* (Harr.), consideration should be given the factors of varietal susceptibility to borer attack, insecticidal effectiveness, and possible phytotoxic effects following the use of insecticides. Previous field tests at Geneva, New York (Carruth & Hervey 1947) have indicated that squash borers were most abundant in varieties belonging to the plant species *Cucurbita maxima* and *C. pepo* and less evident in *C. mosohata.* Although DDT effectively controlled the squash borer it was definitely phytotoxic when dusts prepared from the technical grade (setting point 90° C.) were applied to *C. pepo* and *C. moschata.* This injury was less apparent when similar dusts were applied to *C. maxima.* No phytotoxic symptoms were observed in any species following the use of dusts prepared from DDT of a higher setting point (103 to 105° C.). The present paper is a report of work done during the season of 1947 to verify and extend earlier studies.

The following squash varieties, each representing a separate botanical species, were grown: Blue Hubbard, *Cucurbita maxima,* Table Queen, *C. pepo,* and Butternut, *C. moschata.* The plants were started in pots in a greenhouse and were set out in 6 randomized blocks for each variety, with a 4-hill plat (3 plants per hill) for each treatment, randomized within each varietal replicate. For comparisons with previous work, a one per cent rotenone dust and 3 per cent dusts made from 50 per cent concentrates of two grades of DDT having setting points of 90° C., and 103 to 105° C., respectively, were used. In addition, the following dust mixtures were applied: 10 per cent Sabadilla, 3 per cent bis(methoxyphenyl) trichloroethane, 1 per cent gamma benzene hexachloride, 5 per cent chlordan, 2 per cent chlorinated camphene, and 1 and 2 per cent parathion.[2] All insecticide concentrates were diluted with talc to the required strengths. The plants were set out on June 13 and 14, 1947. All plants, including checks, were dusted with 1 per cent rotenone on June 17 and 24 for cucumber beetle control. Dusts for the control of the squash borer were applied June 29, July 8, 15, 22, and 29 at an average rate of approximately 30 pounds per acre per application, using knapsack duster. Records of foliage injury and borer injury were taken at intervals during the summer. In early October records were made of the number of plants present, plants showing borer infestations, and number and weight of fruits harvested. The data obtained are summarized in table 1.

Fig. 1.—Effect of 3 per cent dusts prepared from grades of DDT having setting points of 90° C. (technical) (left) and 103–5° C. (right) on the foliage of Table Queen squash (*Cucurbita pepo*).

Varietal Susceptibility to Borer Attack.—At harvest a careful examination of all untreated plants showed borer infestations of 12.7 per cent in Table Queen, 40.0 per cent in Blue Hubbard, and none in Butternut. The absence of borers in *Cucurbita moschata* is in agreement with 1946 results and may be due to

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 743, December 24, 1947.

[2] The materials used in 1947 were obtained from the following sources:
American Cyanamid Company: parathion (*Thiophos 3422*);
Coop. G.L.F. Soil Building Service, Inc.: cube root (5% rotenone);
Dow Chemical Company: chlordan (*Dowklor*);
E. I. duPont de Nemours & Co.: technical grade DDT (S.P. 90°C.) (*Deenate*), special grade DDT (S.P. 103–5°C.), benzene hexachloride (*Lexone*), bis (methoxyphenyl) trichloroethane (*Methoxychlor*);
Eastern Magnesia Talc Co.: talc (*Emteo 23*);
Hercules Powder Co.: chlorinated camphene (*Toxaphene*);
John Powell Co.: Sabadilla (*Powco* brand).

Table 1.—Effect of insecticide dusts on foliage, squash borer infestations and yield of 3 squash varieties representing 3 species of the genus Cucurbita. Geneva, N. Y., 1947.

Variety and Species	Treatment	Harvest Data, October 1947				Foliage Injury, July 25, 1947[2]			
		Plants Present[1]	Plants infested with Borers	Fruits Harvested	Average weight of Fruits per Plant	Chlorosis	Necrosis	Distortion	Dwarfing
		Number	*Per Cent*	*Number*	*Pounds*				
Table Queen (*C. pepo*)	Untreated	71	12.7	206	3.0	0	0	0	0
	1% rotenone	67	3.0	242	3.8	0	0	0	0
	10% Sabadilla	67	11.9	221	2.9	0	0	sev	0
	3% DDT (S.P. 90°)	1	0.0	0	0.0	sev	sev	0	sev
	3% DDT (S.P. 103–5°)	64	0.0	250	3.7	0	0	0	0
	3% "Methoxy"[3]	68	1.5	256	3.3	0	lt	0	0
	1% G. Benzene hexachloride	21	0.0	76	3.3	sev	sev	0	sev
	5% Chlordan	65	3.1	235	3.6	0	sev	lt	0
	2% Chlorinated camphene	0	0.0	0	0.0	0	sev	lt	0
	1% Parathion	67	1.5	213	3.2	0	mod	0	0
	2% Parathion	66	6.1	252	4.0	0	mod	lt	0
Blue Hubbard (*C. maxima*)	Untreated	55	40.0	33	8.1	0	0	0	0
	1% rotenone	61	3.3	42	8.1	0	0	0	0
	10% Sabadilla	63	14.3	32	6.3	0	0	sev	lt
	3% DDT (S.P. 90°)	63	3.2	34	5.1	lt	lt	0	0
	3% DDT (S.P. 103–5°)	58	1.7	48	10.2	0	0	0	0
	3% "Methoxy"[3]	63	14.3	45	8.5	0	0	0	0
	1% G. Benzene hexachloride	57	8.8	35	6.2	lt	sev	mod	lt
	5% Chlordan	60	1.7	45	8.7	0	sev	mod	0
	2% Chlorinated camphene	60	5.0	35	6.9	0	0	0	0
	1% Parathion	60	1.6	41	6.1	0	mod	0	0
	2% Parathion	65	0.0	44	7.8	0	mod	lt	0
Butternut (*C. moschata*)	Untreated	68	0.0	104	3.4	0	0	0	0
	1% rotenone	70	0.0	128	4.3	0	0	0	0
	10% Sabadilla	70	0.0	109	3.1	0	0	sev	0
	3% DDT (S.P. 90°)	32	0.0	18	1.1	sev	0	0	sev
	3% DDT (S.P. 103–5°)	64	0.0	105	3.6	0	0	0	0
	3% "Methoxy"[3]	63	0.0	115	4.5	0	lt	0	0
	1% G. Benzene hexachloride	47	0.0	63	2.9	mod	sev	0	sev
	5% Chlordan	71	0.0	137	4.3	0	mod	0	0
	2% Chlorinated camphene	51	0.0	75	3.1	mod	sev	lt	sev
	1% Parathion	67	0.0	116	3.8	0	mod	0	lt
	2% Parathion	64	0.0	97	3.2	0	mod	0	mod

[1] 72 plants set out: 3 plants per hill, 4 hills per replicate, 6 replicates.
[2] Degree of injury: 0—none; lt—light; mod—moderate; sev—severe.
[3] bis(methoxyphenyl) trichloroethane.

a smaller, more compact, more woody stem than is found in the other species observed. Butternut is a relatively small-sized general purpose squash of good quality. If the above results are supported by further tests under other growing conditions, this apparently borer-resistant squash should deserve a much wider use.

INSECTICIDAL EFFECTIVENESS—Comparisons of insecticides were limited by the absence of borers in Butternut and by relatively light infestations in Table Queen. In Blue Hubbard the control produced by both 3 per cent DDT dusts compared favorably with the currently recommended 1 per cent rotenone dust, as did 5 per cent chlordan and 1 and 2 per cent parathion. Ten per cent Sabadilla was relatively less effective, as was 3 per cent bis (methoxyphenyl) trichloroethane. Although 1 per cent gamma benzene hexachloride and 2 per cent chlorinated camphene were effective against borers, they were both seriously phytotoxic.

INSECTICIDE PHYTOTOXICITY.—Striking differences in phytotoxicity were observed between 3 per cent dusts prepared from DDT of two setting points. Dusts prepared from technical DDT (S.P. 90° C.) produced foliage chlorosis which was most evident in Table Queen and Butternut. It was present to a lesser extent in Blue Hubbard, although the symptoms largely disappeared after treatments ceased. Necrotic symptoms were common in Table Queen and to a lesser extent in Blue Hubbard, but were usually absent in Butternut. Practically all Table Queen plants which received dusts prepared from technical grade DDT were killed. No phytotoxic symptoms were observed in plants of any variety treated with dusts prepared from DDT having a higher setting point (103 to 105° C.). Plots receiving dusts prepared from technical DDT (S.P. 90° C.) uniformly yielded fewer and lighter fruit than plots receiving dusts prepared from the higher grade DDT (S.P. 103 to 105° C.). The yield of the latter plots was usually comparable to that of plots dusted with 1 per cent rotenone and showed no adverse effects as a result of the treatments.

Of the other materials tested, benzene

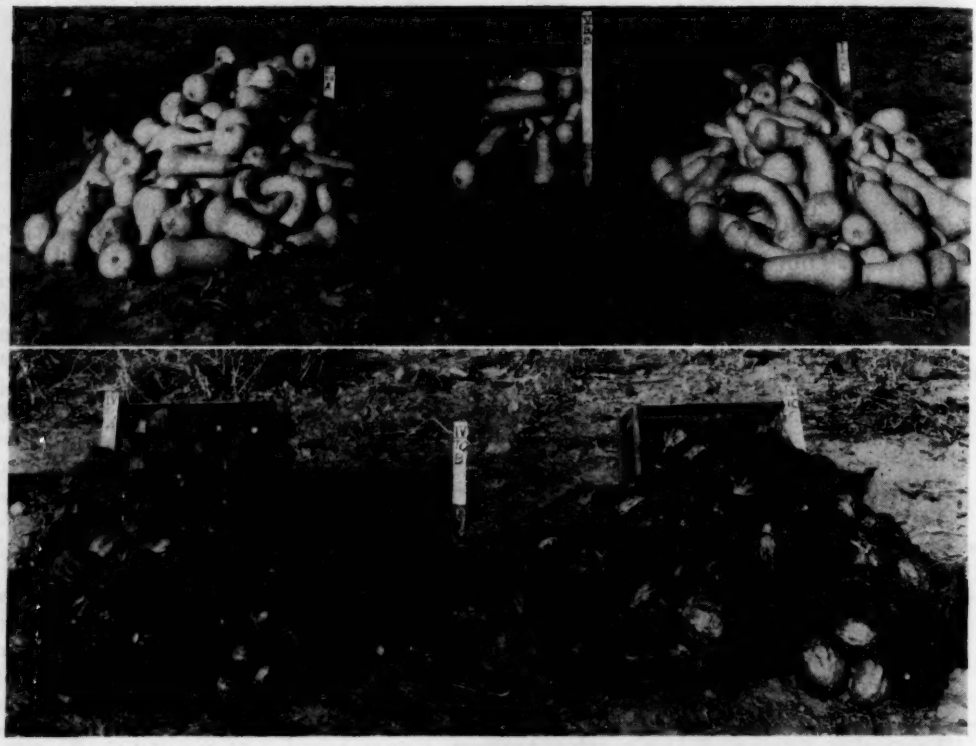

FIG. 2.—Yields of Butternut (*Cucurbita moschata*) (top) and Table Queen (*Cucurbita pepo*) (bottom) squash from untreated plots (left) and from plots receiving 3 per cent dusts prepared from grades of DDT having setting points of 90° C. (technical) (center) and 103–5° C. (right). There was no yield from Table Queen plots receiving dust prepared from technical DDT (bottom center).

hexachloride and chlorinated camphene were the most seriously phytotoxic. Blue Hubbard showed foliage injury following the use of these materials, although the yield was not markedly reduced. Table Queen and Butternut were more seriously affected, both as to foliage and yield. In these varieties the benzene hexachloride treatments destroyed approximately one-third of the plants, although the average weight of the fruits from plants which survived was not greatly affected. Chlorinated camphene dusts killed all plants of Table Queen and approximately one-quarter of the plants of Butternut but did not markedly reduce the weight of fruits from the plants of the latter variety which survived. Dusts containing Sabadilla, chlordan, and parathion produced phytotoxic foliage symptoms which disappeared after treatment ceased and did not significantly affect yields (Table 1).

DISCUSSION.—An unexpected development in this study has been the resistance of Butternut to squash borer attack both in 1946 and 1947. The wider use of this and other varieties exhibiting possible resistance to borer injury, both by growers and by plant breeders, could lessen the need for using insecticides under some conditions.

There appear to be differences between squashes of the 3 species of the genus *Cucurbita* studied, both as to susceptibility to squash borer attack and to insecticide injury. In order of borer resistance the species ranked: *moschata*, *pepo*, *maxima*, although only the first was outstandingly resistant. In order of resistance to insecticide injury the species ranked: *maxima*, *moschata*, *pepo*, although all species were injured in some cases.

A number of insecticides have now been found effective against the squash borer, although the problem of phytotoxicity

must be considered before using any of the newer insecticides in place of the previously recommended rotenone.

With DDT it appears that the danger of plant injury can be eliminated by using a product approaching aerosol grade in setting point. DDT of lower setting point, such as the present technical grade, should be avoided for use on cucurbits. In the present studies squashes of the hubbard type were somewhat more resistant to foliage injury from technical grade DDT, although the size of the harvested fruits was adversely affected. Further evidence of the danger of using technical grade-DDT on cucurbits is found in a recent paper by Brown & Alban (1947) who report at least some damage in all of 42 varieties, including squashes, pumpkins, muskmelons, and watermelons, receiving sprays containing DDT. Unless a grade of DDT known to be safe to cucurbit foliage is available, some other insecticide of known safety should be used for squash borer control.

Of the newer insecticides tested, benzene hexachloride and chlorinated camphene, as used in 1947, were too phytotoxic to be considered further. The chlordan and parathion dusts used were both effective against the squash borer but gave indications of foliage injury. The plants outgrew this injury after treatments ceased and in most cases the yields were not affected. The possibility of using reduced dosages of chlordan and parathion should be considered in planning further tests.

SUMMARY.—In experiments at Geneva, New York for the control of the squash borer, *Melittia cucurbitae* (Harr.) in 1947 observations were made on the factors of varietal susceptibility to borer attack, effectiveness of insecticides, and insecticide phytotoxicity on Blue Hubbard, Table Queen, and Butternut squash, representing the plant species *Cucurbita maxima, C. pepo,* and *C. moschata,* respectively. Untreated plants of Butternut were free from borer infestations, possibly because of a small, compact, woody stem which is not well adapted to the usual feeding habit of the insect. Effective insecticidal control of the borer was obtained with the following dusts: 1 per cent rotenone, 3 per cent DDT (setting point 103 to 105° C.), 5 per cent chlordan and 1 and 2 per cent parathion. Ten per cent Sabadilla was relatively less effective as was 3 per cent bis (methoxyphenyl) trichloroethane. Although 3 per cent DDT (setting point 90° C.), 1 per cent gamma benzene hexachloride and 2 per cent chlorinated camphene were effective against borers, they were all seriously phytotoxic. Striking differences in phytotoxicity were observed between 3 per cent DDT dusts of two setting points. A dust prepared from technical DDT (S.P. 90° C.) produced foliage chlorosis, dwarfing and necrosis of Table Queen foliage and killed practically all plants. This dust produced foliage chlorosis and killed over half the plants of Butternut but was less injurious to Blue Hubbard, although yields of the latter variety were reduced. Phytotoxic symptoms were absent in all cases following the use of dusts prepared from DDT having a setting point of 103 to 105° C. Dusts containing chlordan and parathion in some cases produced characteristic symptoms of foliage injury which were later outgrown and did not appear to affect the yield.—12-31-47.

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Hexaethyl Tetraphosphate and Tetraethyl Pyrophosphate as Aerosols against the Two-Spotted Spider Mite

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When the work being reported was started in 1946, hexaethyl tetraphosphate was a relatively new insecticide reported by American Science Teams in Germany, and about which little was known. Because of its ease of production in the laboratory, and its potential qualities as a substitute for nicotine, it was decided to make a series of tests of the material.[2]

The first field to be investigated was the effect of hexaethyl tetraphosphate as a direct fumigant. This study was decided upon because the author's primary interest was in the field of greenhouse pests, pests of roses in particular. It was of the utmost interest to learn the part that fumigation might play in the future investigations of the hexaethyl tetraphosphate as an aerosol. Sprays could also have been made a part of this investigation, but the ease of application of fumigants and aerosols compared with the work entailed for the commercial greenhouse operator to spray his plants decided against the investigation of the materials used as sprays.

The high vapor pressure of hexaethyl tetraphosphate gave the first impression that the material might hold little hope of being employed as a fumigant, but an equipment chain was devised to prove or disprove this contention. The chain was devised so that the test could be run in duplicate. The equipment consisted of first, a spiral gas washing tower containing water to give a high humidity in order to observe the part which water might play in the use of the ester as a fumigant, and the effect of hydrolysis on the ester. A second gas washing tower followed containing a mixture of equal parts of hexaethyl tetraphosphate and distilled water. These in turn were connected by means of a "T" tube to two vacuum type desiccators, having a long tube and a shorter tube for the air exit tube. The bottom space in the desiccators was covered with a glass plate to give a flat surface on which to place the vials containing the aphid infested leaves to be employed in this test. The desiccators were, in turn, connected to individual gas flow meters to measure the rate of flow of the air through the desiccators. The meters were connected by another "T" tube to a venturi type water vacuum pump. By regulating the flow of the water through the venturi, the amount of air drawn through the chain could be controlled. The flow of air through the set-up was regulated at about 0.1 cubic foot each 2 minutes through each desiccator. Successive tests were run for 2 hours each over a period of 24 hours, using the same material but placing new aphid infested leave in the desiccators, and the count determined by the number of aphids which fell off of the leaves enclosed in the desiccators. (This method of evaluation was found satisfactory since very few aphids fell from the plants when air alone was run through the equipment.) The temperature was noted for each test, varying from 25 to 27° C. for the first run, and from 25° to 30° on the second complete run. The complete results of these experiments are shown in figure 1.

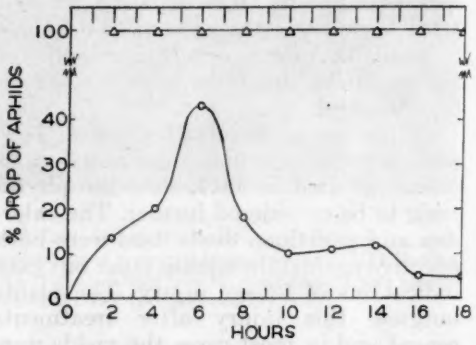

FIG. 1.—Toxicity of hexaethyl tetraphosphate to aphids. (Hexaethyl tetraphosphate alone, (△); and with water (○)).

It had been hoped that *Macrosiphum*

Eastern Branch Program.

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[2] Shortly after the preliminary tests were commenced, it was learned that the Monsanto Chemical Company of St. Louis, Missouri, and the Victor Chemical Works of Chicago, Illinois were in pilot plant production of the ester, and samples were obtained from these two sources and employed in the following tests.

rosae, L., could be used for these tests, but a sufficiently large culture could not be built up for this purpose, so the potato aphid, *Macrosiphum solanifolii*, Ashmead, was used instead.

Because of the curves obtained, it was thought that a possible product of hydrolysis might be giving a temporary increased toxicity to the material, so a second test was run with the pure hexaethyl tetraphosphate alone at low humidity. To eliminate hydrolysis of the material, concentrated sulfuric acid was used in the first gas washing tower to dehydrate the air, while the second tower contained only hexaethyl tetraphosphate. The only water available to affect the vapors drawn over the leaves was that in the vials containing the leaves. The curve resulting from this test was a horizontal straight line at a higher level of toxicity, proving that hexaethyl tetraphosphate vapor itself was more toxic than any possible volatile hydrolysis product from the water-hexaethyl tetraphosphate mixture. (Temperatures of the second test varied from 29° to 31° C.)

From the results of these tests it may be concluded that the pure hexaethyl tetraphosphate has a definite high fumigation effect, but that on the addition of water, hydrolysis occurs which greatly reduces the fumigation potential of the ester. A higher level of toxicity as a fumigant is given by the pure material compared to a mixture of the ester and water, as is shown by the reduction of the knock-down of the aphids when the mixture was used. The rise in the toxicity curve for the mixture may possibly be the result of the hydrolysis of products present other than tetraethyl pyrophosphate (which is now thought to be the active toxic ingredient of hexaethyl tetraphosphate) so rapidly as to affect the rate of volatilization of the tetraethyl pyrophosphate which hydrolyzes rather slowly, and therefore, that the tetraethyl pyrophosphate volatilizing at this point from the mixture, may be the reason for the rise in the toxicity curve of the mixture.

Because of the ease of application of aerosols, it was next decided to find out the effectiveness of hexaethyl tetraphosphate when applied in a greenhouse as a liquefied gas aerosol. About the time that this work was starting, some small quantities of tetraethyl pyrophosphate became available, and it was then decided to expand the investigations of the aerosols to include the tetraethyl pyrophosphate. The earlier test for fumigant action could not be run with the tetraethyl pyrophosphate due to the small sample received. The aerosol use of the materials seemed to hold high promise in view of the results obtained from the preliminary fumigation effect tests.

The first detail investigated before starting the aerosol comparisons was that of the solubility of these materials in the most suitable liquefied gases. Tests disclosed a very low degree of solubility in *Freon 12*, but that both materials were completely soluble in methyl chloride, so this gas was selected for use with the esters for formulating the aerosols to be studied.

The dispenser used for the work with the aerosols was a methyl bromide fumigant proportioner[3] with the outlet valve equipped with a number 5 oil burner nozzle. This nozzle was used in all of the tests. As an added safety feature, the 100-milliliter cylinders were wrapped with cellulose tape, and a slotted metal cylinder was attached over the glass cylinder with spring clips to protect the operator from flying glass in the event of the shattering of the cylinder by gas pressure.

Concentrations of the aerosol solutions were in all cases, down to 1 gram of insecticide per 1000 cubic feet of space, a 20-per cent solution in methyl chloride (this by volume). All concentrations below 1 gram per 1000 cubic feet were made up to 5 ml. of solution with methyl chloride, due to the inadequacy of the dispenser to handle smaller amounts of the solution.

Spider mite counts were made with a binocular dissecting microscope, and two hand counters were used for registering the dead and living mites. Three counts were made of the mite population. The first at 24 hours after the treatment, the second at 3 days and the third at 7 days after the treatment. The life history of the red spider mite gives some indication of the difficulty of making counts of the actual mortality of the mites after treatment. The mites pass through a quiescent pre-molt period between the various active stages. Kill of these stages can be determined only after a period of several

[3] Manufactured by Arrow Products Company, Carlstadt New Jersey.

days when the dead mites become definitely discolored. Young which hatched from eggs immediately following the treatment were counted, but no egg counts were made. The quiescent stages cannot be accurately counted 24 hours after treatment since it is impossible in this stage to tell whether or not the mites have been affected by the toxicants. At the same time the counts are influenced by the hatching of the eggs, providing that they have not been affected by the materials used in the treatments.

In the first (24-hour) count in each test, only mites in the active stages were counted, and only those dead mites which did not give the appearance of having been dead for more than 24 hours. At the 3 day and 7 day counts it was possible to determine which of the inactive stages were dead and which were still alive, and so it was possible to count these. On the other hand, it was impossible to determine which of the dead had been killed by the treatment, and which were dead prior to the treatment, so all dead were counted. By this method, only the first-day count was reliable for showing actual toxicity of the aerosols, the 3 and 7 day counts serving only to show build up of the infestation on the treated plants. The leave removed from the plants were selected at random from all parts of the plants, and from all of the plants as a group for counting. After counting, the leaves were disposed of, meaning that 30 leaves were taken for all of the counts over the 7-day period.

A check using only methyl chloride was run, and counts were made in the same manner.

Final results of all of the tests were then computed using Abbott's[4] method to correct for normal mortality and build up of the check infestation as related to treated populations.

The two-spotted spider mite, because of its economic importance to rose growers, was chosen as the test for these experiments. A culture is continuously maintained on potted rose plants, variety Briarcliff, in the Entomology greenhouse at Cornell University. All stages of the mites were on the plants used, and entire plants in pots were employed in the tests.

In all of the tests run, four complete rose plants in pots were placed in the fumigation chamber or the greenhouse section used, at least an hour prior to treatment to allow the plants, pots, and soil to reach the temperature of the chamber in which they were to be treated.

At first tests were run to determine the influence of humidity. The greenhouse section of 1650 cubic feet was used for high humidity, and the fumigation chamber of 111 cubic feet, used for the low humidity tests. High humidities were obtained by thoroughly wetting down the section, bench, and cement wall foundation before treatment. By this means it was possible to obtain and maintain a measured relative humidity of from 90 to 95 per cent in the section throughout the 6-hour fumigation period.

The low humidity tests were run in the fumigation chamber because of the smaller space involved, and the sealed door which aided in maintaining the desired conditions. The pots were covered with heavy kraft paper, slit to encircle the stem of the plant, and held in place with rubber bands. Anhydrous calcium chloride was placed in large shallow pans and located at different levels to aid in lowering humidity. By this means it was possible to maintain a measured relative humidity of from 50 to 60 per cent in the sealed chamber. No significant difference was noted between those tests run at high relative humidities and those run at low relative humidities.

Temperatures in all treatments were maintained at as near 70° F. as possible. This was more easily accomplished in the chamber than in the greenhouse section, which was subject to temperature changes due to the sun coming out during the treatment. To minimize the possibilities of this occurrence, all tests were run on cloudy, overcast, days, or at night. During these times, temperature was maintained, as in the chamber, by thermostat set for 70° F. Temperatures actually maintained were $70° \pm 4$ degrees.

All treatments were made by the complete dispersal of an aerosol solution of measured dose which had been prepared just prior to use, and using the same dispenser. (Preparation of the solution just prior to use eliminated the storing of the highly toxic aerosol solutions in the laboratory.) The operator released the aerosol in the greenhouse section from the dispenser holding it above and directing it over (never into) the plants. The dis-

[4] Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. JOUR. ECON. ENT., 18: 265–267.

penser was manipulated so as to give an even distribution of the aerosol solution within the chamber or section. Introduction of the aerosol into the chamber was through a 4-inch port which sealed, after releasing the aerosol, with a screw in cover in the lower right side of the cabinet. Precautions taken were the wearing of an *M.S.A. Industrial Gas Mask* equipped with a *GMA-1* cannister, as well as wearing rubber gloves pulled over rolled down shirt sleeves, and keeping the shirt completely buttoned so as to give the operator maximum protection from the aerosol.

Table 1.—Hexaethyl tetraphosphate.

Dose in Grams per 1000 Cu. Ft.	Period	No. Dead	No. Living	Per Cent Kill
0.125	24 Hrs.	484	623	41.5
	3 days	322	570	31.4
	7 days	378	653	33.6
0.17	24 Hrs.	534	571	46.3
	3 days	462	684	35.9
	7 days	352	608	33.6
0.25	24 Hrs.	477	360	55.3
	3 days	540	483	49.3
	7 days	369	566	36.5
0.50	24 Hrs.	619	461	55.6
	3 days	642	737	42.6
	7 days	747	791	46.1
1.0	24 Hrs.	577	323	62.7
	3 days	753	457	59.4
	7 days	563	709	41.6
3.0	24 Hrs.	724	123	84.9
	3 days	817	503	59.1
	7 days	1039	1558	37.0
5.0	24 Hrs.	1157	213	83.9
	3 days	1089	533	64.7
	7 days	994	894	50.3
7.0	24 Hrs.	673	56	92.0
	3 days	622	149	79.3
	7 days	697	544	54.0
9.0	24 Hrs.	717	100	87.3
	3 days	644	178	76.7
	7 days	1378	858	59.7
11.0	24 Hrs.	634	102	85.6
	3 days	893	233	77.8
	7 days	789	435	60.1

Check		No. Dead	No. Living	Per Cent Living
75 ml. methyl chloride	24 Hrs. 3 dyas 7 days	31 77 36	776 1042 731	96.2 93.1 95.3

After a 6-hour exposure period, the chamber or section was aired and the plants removed to the regular rose section of the greenhouse where they were kept separated in test groups from the other plants. This permitted standard conditions for all the rose plants involved in the tests throughout the testing periods.

A check was run to determine what effect, if any, the methyl chloride had on the plants and test insects. To determine this, the largest amount of methyl chloride employed in any of the previous tests was used in the greenhouse section containing four Briarcliff rose plants in pots and containing an infestation of red spider as was used in all previous tests.

For this test 75 ml. of methyl chloride were employed, with the results shown in tables 1 and 2.

The results from this check were then used in the computation, by Abbott's formula, of the per cent of kill given by the tests of the two insecticides employed as aerosols. Successive counts were made 24 hours, 3 days, and 7 days after the treatments to enable an estimate to be made of the effectiveness of the treatments against the various stages of the mites and eggs.

The principal experiment was a comparison of the toxicity of hexaethyl tetraphosphate and tetraethyl pyrophosphate against the two-spotted spider mite. It had been planned to test the hexaethyl tetraphosphate and tetraethyl pyrophosphate against the rose aphid, *Macrosiphum rosae*, L., as well as the spider mite, but an insufficient culture made this impossible in view of the large population counts required for statistical significance. In a few preliminary tests where the aphid was used, a complete kill always resulted from the aerosols used, including those down to the lowest concentrations, showing the high degree of susceptibility of the aphids to these insecticides.

The results of the experiments are given in tables 1 and 2. Percentage of kill was derived by applying Abbott's formula to the results as compared to the information obtained from the check. In computing these results, the percentage of living spider mites in the check corresponding to the day of the treatment counts was used.

These results are illustrated in figure 2. From the results obtained, it would appear that the optimum dose would be about three grams per 1000 cubic feet, provided the plants being treated would permit this high dosage without sustaining injury. This dosage was selected as optimum because higher dosages gave only

slightly higher kill and increased the chances of burning the plants.

Under the conditions of these tests it is again shown that the optimum dosage is about 3 grams per 1000 cubic feet and that over this dosage there is no significant increase in kill to make it economically worth while to use higher concentrations of the material in treatment. The optimum dose of 3 grams of tetraethyl pyrophosphate gives a higher percentage of mortality than the optimum dose, also three grams, of hexaethyl tetraphosphate, while injury to plants is about the same, and certainly no greater, than that caused by hexaethyl tetraphosphate. These results further show the increased toxicity of the tetraethyl pyrophosphate as compared to the hexaethyl tetraphosphate.

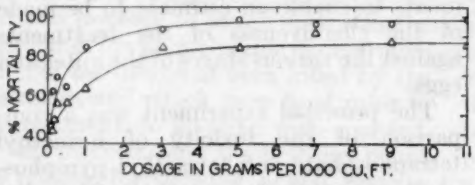

FIG. 2.—Dosage and toxicity of hexaethyl tetraphosphate (△) and tetraethyl pyrophosphate (○).

When these results are further compared on logarithmic-probability paper it may be seen that the lines of their respective dosage-toxicity (per cent kill) curves are almost parallel, which tends to support the belief that tetraethyl pyrophosphate is the toxic ingredient of hexaethyl tetraphosphate, and that hexaethyl tetraphosphate is a mixture of phosphates of various kinds. From the results obtained and plotted on the logarithmic-probability scales, it is also found that the tetraethyl pyrophosphate used is about three times as toxic as the hexaethyl tetraphosphate employed in these tests over the complete range of concentration and under the experimental conditions encountered. These results are shown in figure 3.

At the time that these tests were run, the actual tetraethyl pyrophosphate content of the commercial sample was not known. It was only recently that we have received the results of the analysis of the sample used in these tests, and find that it contained 25 per cent of pure distillable tetraethyl pyrophosphate. This is in agreement with the results obtained if it is assumed that the sample of hexaethyl tetraphosphate employed in these tests contained an average of 8 to 10 per cent of tetraethyl pyrophosphate as the active toxic ingredient.

The median lethal dose obtained through these tests from figure 3 is 0.25 gram per 1000 cubic feet for hexaethyl tetraphosphate, and 0.08 gram per 1000 cubic feet for tetraethyl pyrophosphate, showing the tetraethyl pyrophosphate to be about three times as toxic, under the conditions of testing, as the hexaethyl tetraphosphate used, which is now found to be about correct in view of the active toxic ingredient in the tetraethyl pyrophosphate and the assumed toxicant (tetraethyl pyrophosphate) content of the hexaethyl tetraphosphate sample herein employed.

Table 2.—Tetraethyl pyrophosphate.

Dose in Grams per 1000 Cu. Ft.	Period	No. Dead	No. Living	Per Cent Kill
0.063	24 Hrs.	584	692	43.7
	3 days	452	671	35.8
	7 days	260	769	21.6
0.125	24 Hrs.	594	349	61.5
	3 days	433	550	39.8
	7 days	426	611	38.2
0.25	24 Hrs.	547	240	68.3
	3 days	718	432	59.6
	7 days	559	673	42.7
0.50	24 Hrs.	635	342	63.6
	3 days	620	485	62.9
	7 days	479	576	42.7
1.0	24 Hrs.	798	140	84.5
	3 days	556	300	62.4
	7 days	627	456	55.8
3.0	24 Hrs.	524	35	93.5
	3 days	536	405	53.8
	7 days	621	597	48.6
5.0	24 Hrs.	822	14	98.2
	3 days	1271	328	78.0
	7 days	445	120	77.8
7.0	24 Hrs.	531	21	96.0
	3 days	1196	117	89.7
	7 days	1003	168	85.0
9.0	24 Hrs.	726	25	96.6
	3 days	1185	279	79.5
	7 days	914	416	67.2
11.0	24 Hrs.	916	8	99.0
	3 days	915	128	86.8
	7 days	1236	538	68.2

Check		No. Dead	No. Living	Per Cent Living
75 ml.	24 Hrs.	31	776	96.2
methyl	3 days	77	1042	93.1
chloride	7 days	36	731	95.3

The next investigations on these aerosols was to undertake the particle size measurements. This work was accomplished with the use of a microscope equipped with a filar micrometer eyepiece. Aerosol solutions of the same concentrations as those used with the highest and near the lowest dosages were discharged from the applicator in the direction of a glass slide having a thin film of mineral oil which would catch, but not rapidly dissolve, the hexaethyl tetraphosphate and the tetraethyl pyrophosphate. The slides were then immediately placed under the microscope and representative measurements of 200 particles were taken, that is, all particles in each field were measured. The results of these observations showed that the largest percentage of particle sizes fell between 1 to 2 microns except for the hexaethyl tetraphosphate aerosol of 1 gram active ingredient per 1000 cubic feet, in which case the largest per cent of particles were about 2 to 3 microns in diameter. The largest number of particles of all of the aerosol solutions ranged from 1 to 8 microns in diameter.

The difference of particle size of the aerosol mixture containing 1 gram of hexaethyl tetraphosphate in methyl chloride for a 1000-cubic foot treatment as compared to the other particle size measurements of the other concentrations is difficult to account for. It may possibly be due to evaporation of the smaller particles on the surface of the mineral oil or their agglomeration due to a short delay in measuring their sizes.

In view of the importance in many cases of particle size to toxicity, particle size determinations would seem to be of great significance. Although the author can draw no conclusions as to the relationship between the particle size and toxicity of the materials used in the test presented, these results may prove of interest in future work with the same materials employed with different particle sizes.

SUMMARY.—In tests employing *Macrosiphum solanifolii*, Ashmead, pure hexaethyl tetraphosphate has a definite and high fumigation effect, but on the addition of water, hydrolysis occurs which reduces the fumigation potential of the ester. The toxicity curve (Fig. 1) obtained from the water-hexaethyl tetraphosphate mixtures would seem to indicate that there is a good possibility that hydrolysis of the material aids in the volatilization of the tetraethyl pyrophosphate present, or that some other volatile toxic hydrolysis product is evolved prior to complete hydrolysis of the hexaethyl tetraphosphate into non-toxic components.

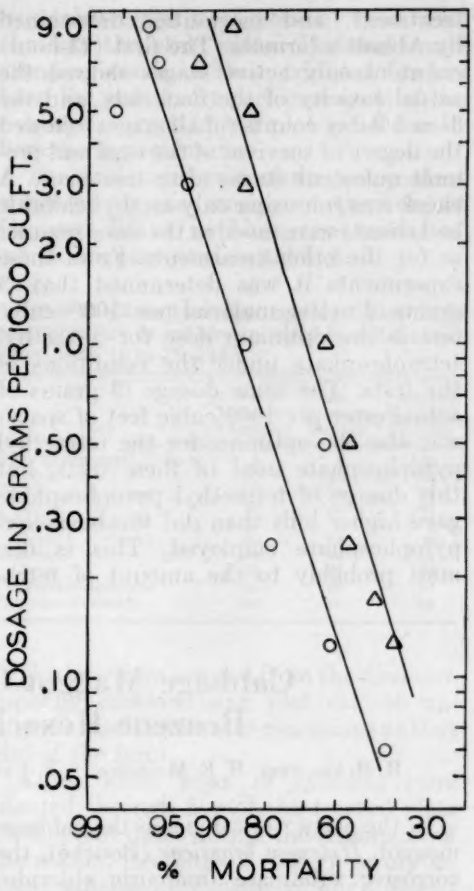

FIG. 3.—Dosage and toxicity of hexaethyl tetraphosphate (△) and tetraethyl pyrophosphate (○) plotted on logarithmic probability scales.

The two-spotted spider mite, *Tetranychus bimaculatus*, Harvey, was used as the test species in a series of experiments designed to evaluate the comparative toxicities of hexaethyl tetraphosphate-methyl chloride mixtures and tetraethyl pyrophosphate-methyl chloride mixtures as aerosols. Twenty per cent solutions were used down to concentration of 1 gram of active ingredient per 1000 cubic feet of space. Below this concentration, the aerosol solutions were made up to 5 milliliters with methyl chloride. Counts were made at 24 hours, 3 days, and 7 days after

treatment, and mortalities determined by Abbott's formula. The first (24-hour) count of only active stages showed the actual toxicity of the materials, and the 3- and 7-day counts (of all stages) showed the degree of survival of the eggs and pre-molt quiescent stages after treatment. A check was run using only methyl chloride and counts were made in the same manner as for the other treatments. From these experiments it was determined that 3 grams of active material per 1000 cubic feet is the optimum dose for hexaethyl tetraphosphate under the conditions of the tests. The same dosage (3 grams of actual ester per 1000 cubic feet of space) was also the optimum for the tetraethyl pyrophosphate used in these tests, but this dosage of tetraethyl pyrophosphate gave higher kills than did the hexaethyl pyrophosphate employed. This is due most probably to the amount of tetraethyl pyrophosphate (as the distillable ester) present in these two samples. There seemed to be no significant difference of results between treatment run at high and low humidities. These experiments also showed tetraethyl pyrophosphate to be about three times more toxic than the sample of hexaethyl tetraphosphate used in these tests. Again it may be assumed that this difference is directly concerned with the amount of actual distillable tetraethyl pyrophosphate present in the two samples of materials used for testing. Almost parallel dosage-mortality curves obtained on logarithmic-probability scales for the hexaethyl tetraphosphate and tetraethyl pyrophosphate used would indicate that the probable toxicity of hexaethyl tetraphosphate is due to the tetraethyl pyrophosphate present in it, and in ratio to the concentration present. —11-20-47.

Cabbage Maggot Control by the Use of Benzene Hexachloride in the Soil[1]

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In the early work done on the cabbage maggot, *Hylemya brassicae* (Bouché), the corrosive sublimate (mercuric chloride) treatment soon figured as the most generally dependable and practical method of control. Later, Glasgow (1929) and Friend (1932) showed that the milder calomel (mercurous chloride) would give equally good control and was easier and safer to apply. Work has continued since the discovery of the effectiveness of mercury salts for three main reasons: the mercury salts are too expensive (Dills 1944); they have been short in supply at times (Carlson *et al.* 1947); they do not give a high enough degree of control when infestations are high (Whitcomb 1944). Other methods of control, such as use of tar paper discs and screening (Parrott 1917; Glasgow 1925; Schoene 1914) require too much labor or are utterly impractical in commercial plantings of cole crops, whether grown for produce or for seed.

Crucifers in general are able to withstand considerable maggot injury without succumbing, except in the early stages and at the time of transplanting. In the case of cole crops grown for their leafy or flower products (cabbage, broccoli, etc.), the presence of some maggots on the roots after the plants are established has not been considered serious. The fleshy rooted crucifers (radishes, turnips, etc.), however, are greatly reduced in market value by even slight maggot injury. There has been no adequate recommendation for maggot control on these root crops.

With the advent of DDT and the several newer synthetic organic insecticides, hope has again arisen for the discovery of a better, cheaper and more readily available and easily applied material for the control of the cabbage maggot. Fulton (1946) and Grayson & Poos (1947) have shown that both DDT and benzene hexachloride have distinct possibilities as soil insecticides for the control of the southern corn rootworm. McLeod (1946a and 1946b) reported good control of the onion maggot, *Hylemya antiqua* (Mieg.), with sprays and dusts of benzene hexachloride,

[1] Published as Technical Paper No. 520 with the approval of the Director of the Oregon Agricultural Experiment Station. Contribution of the Department of Entomology.

but found the material to be extremely phytotoxic when mixed with the soil or applied as a seed treatment.

Preliminary experiments at the Oregon Agricultural Experiment Station with benzene hexachloride did not show promise against the symphilid, *Scutigerella immaculata* Newport, when the material was used as a seed treatment or when it was applied to the soil by means of a fertilizer attachment in the plow sole. Encouraging results against the symphilid were obtained, however, when benzene hexachloride was injected as a solution into the soil by means of a power soil fumigator and when it was spread on the surface and mixed into the soil with a rotary tiller. Controls of the western spotted cucumber beetle larvae, Collembola and other soil pests were indicated also with the latter method of application.

In the spring of 1947 strips of land at the Entomology Farm in Corvallis were treated with several insecticides. The solid materials were applied to the surface of the ground on May 18th with a hand-drawn fertilizer applicator covering a 3-foot swath. The plots were then thoroughly cultivated with a rotary tiller to a depth of 7 to 8 inches. The one soil fumigant used was applied with a power soil injector after the ground had been prepared by the rotary tiller.

The amounts of proprietary insecticides used were more or less arbitrary and are presented in Table 1.

Check or untreated strip plots of varying widths were located between the treated ones.

On May 20th single rows of 29 different vegetable crops were planted from seed through the strip plots. The most outstanding result of these trials so far has been the practically perfect control of the cabbage maggot in the plot treated with benzene hexachloride.

The first indication of maggot control appeared in the scoring of the row of Crimson Giant radishes, the results of which are presented in table 2.

Table 1.—Amounts of five different insecticides and one soil fumigant applied to the soil at Entomology Farm, Corvallis, 1947.

MATERIALS	POUNDS ACTUAL INGREDIENT PER ACRE	ESTIMATED CONCENTRATION IN SOIL. POUNDS/1000 CU. FT.[1]
Dichloro-diphenyl-dichlorethane 50% wettable	106.8	3.922
Hydroxypentamethylflavan 30% conc.	38.4	1.410
DDT 50% wettable	137.5	4.701
Benzene hexachloride (Technical grade 10% gamma isomer content)	27.5 (gamma)	1.010 (gamma)
Chlordan, (5% dust in talc)	27.5	1.010
Chlorinated camphene. 5% dust in	27.5	1.010
Propylenedichloride[2]	288.0	—

[1] Estimation of amount of actual materials based on assumption that a uniform distribution was secured in the top 7.5 inches of soil by the rotary tillage.
[2] *Dowfume N.*

Table 2.—Results of first scoring for cabbage maggot injury to radishes planted in soil-treated plots, June 19 to 25, 1947.

PLOT	NO. RADISHES EXAMINED	NO. RADISHES INJURED	PER CENT RADISHES INJURED
Hydroxypentamethylflavan	5	5	100
Check	50	45	90
DDT	50	46	92
Check	30	26	87
Benzene hexachloride	50	0	0
Check	20	19	95
Chlordan	50	36	72
Check	30	27	90
Chlorinated camphene	50	46	92
Propyline dichloride	50	44	88

No data were secured from the dichloro-diphenyl-dichlorethane plot due to unfavorable soil and water conditions at that end of the farm.

Three more rows of radishes were planted through five of the treated plots on different dates during the remainder of the season. Readings of maggot injury on these radishes were made on four different dates between August 6 and September 19. Data on the combined and averaged scorings of these radish rows are presented in table 3.

To check the possibility of repellent action exerted by the benzene hexachloride 20 radishes taken from this plot on June 19th were examined carefully for the presence of *Hylemya* eggs. One or more eggs were found on all of the radishes. The 20 radishes were further examined under a dissecting microscope and in several cases it was found that the eggs had hatched and slight feeding by the maggots had occurred. The feeding injury, however, had not penetrated through the red skin of the radishes and could only be noticed under magnification.

To supplement these results, a series of small plots were laid out in which eight different concentrations of benzene hexachloride were applied to the soil and worked into the top inch or two with a garden rake. The treated plots were 3 feet

by 24 feet, unreplicated and separated by untreated check plots of the same area. Radishes were planted July 5th in rows 18 inches apart across the short dimension of these plots with a hand planter. The benzene hexachloride used was a dust containing 1 per cent of the gamma isomer (sifted onto the ground with an improvised shaker), since the amounts to be applied were small and considerable volume

Table 3.—Combined results of four scorings for cabbage maggot injury to radishes planted in soil-treated plots, Aug. 6 to Sept. 19, 1947.

Plot	No. Radishes Examined	No. Radishes Injured	Per Cent Radishes Injured
DDT	222	148	67
1st Check	117	77	66
Benzene hexachloride	314	9	3[1]
2nd Check	144	89	62
Chlordan	197	131	67
3rd Check	98	68	69
Chlorinated camphene	121	89	74
4th Check	75	36	48
Propylene dichloride	122	60	49

[1] Scoring was severe. All injured radishes in benzene hexachloride treated plots were very lightly injured and were considered marketable.

was desirable for accurate distribution. The rake method of mixing was used so that the results of the test might be applicable to home gardens.

Three readings of the plots for maggot injury were made between August 13th and September 4th from the July 5th planting. The results of the three scorings are presented separately in table 4 in order to show that the protection afforded by this method of benzene hexachloride application decreased with increased times of exposure. The radishes had reached marketable size at the time of the first scoring, however, and maggot control beyond this date would have a limited commercial value.

A comparison of these small plots with the large, rotary tilled benzene hexachloride plot is of interest. The rate of application in the larger plot was at the rate of 1.01 pounds per 1000 cubic feet of soil (27.5 pounds per acre). This amount provided practically 100 per cent protection from the maggots with all varieties of crucifers grown for at least four months. The rate of application in the smaller radish plots ranged from 0.0918 pounds to 3.305 pounds per 1000 cubic feet of the gamma isomer (8 ounces to 18 pounds gamma per acre). The five heavier dosages afforded only fair and erratic protection

Table 4.—Results of three scorings for cabbage maggot control on radishes from one planting in plots treated with benzene hexachloride.

	Rate of Application γ-Benzene Hexachloride		Per Cent of Uninjured Radishes[1]		
Plot No.	Pounds per Acre	Pounds per 1000 Cu. Ft.[2]	Aug. 13th Scoring	Aug. 21st Scoring	Sept. 4th Scoring
1	0.5	0.0918	64	36	0
2	1.5	0.275	58	46	0
3	3.0	0.550	74	38	0
4	6.0	1.101	90	36	20
5	9.0	1.652	86	52	26
6	12.0	2.203	96	64	18
7	15.0	2.755	76	42	22
8	18.0	3.305	84	66	44
Average of the seven checks:			53	27	2

[1] 50 radishes from each plot examined on each scoring.
[2] Estimations based on assumption that the benzene hexachloride was distributed through the top 1.5 inches of soil by the use of a garden rake. Plots had been rotary tilled prior to application of the insecticide.

for a period of 39 days. Failure of the benzene hexachloride in the small plots to give comparable protection from the maggot is believed to be due largely to the method and depth of mixing in the soil. The radishes were severely culled in the scorings and many in the small treated plots were found to have maggot injury only in the tap root below the edible bulb and thus below the level of benzene hexachloride-mixed soil.

That benzene hexachloride soil treatment is a distinct possibility in cabbage maggot control was further demonstrated by readings on four other varieties of Cruciferae. These crops (rutabaga, southern curled mustard, Italian broccoli and early purple kohlrabi) were planted from seed through the large, rotary tilled plots on May 20, 1947. The results of the scoring of these vegetables for cabbage maggot injury are condensed into table 5.

The ability of cruciferous plants to grow well in benzene hexachloride-treated soil free from cabbage maggot injury shows promise for the vegetable seed industry. Shortly after the mustard had bolted, it was noticed that the plants growing in the benzene hexachloride plot were not only taller, but more prolific. As the season advanced it was found that these plants matured 1 to 2 weeks before those in the other plots. The seed was harvested from the benzene hexachloride, DDT and chlordane plots as well as from a section of equal length from the check row. The number of individual mustard plants from each plot was noted and the seed was cleaned, dried and weighed. The

Table 5.—Results of scoring for cabbage maggot injury on four different cruciferous crops grown in soil-treated plots.

PLOT	PER CENT OF PLANTS MAGGOT INJURED			
	Rutabaga[1]	Mustard[2]	Broccoli[3]	Kohlrabi[4]
Dichloro-diphenyl-dichloroethane	75	90	80	100
Hydroxypentamethylflavan	70	100	—	100
DDT	90	70	70	100
Benzene hexachloride	0	0	0	0
Chlordan	57	80	30	100
Chlorinated camphene	80	90	80	100
Propylene dichloride	—	90	—	100
Average of checks[5]	78	90	55	100

[1] 10 to 30 plants from each plot examined on June 25th and on July 15th.
[2] 10 to 12 plants from each plot examined on July 15th.
[3] 10 plants from each plot examined on July 15th.
[4] 11 to 63 plants from each plot examined on Aug. 7th.
[5] 40 to 142 plants from untreated checks examined in the scoring of each vegetable variety.

Table 6.—Effect of three soil treatments on the yield of southern curled mustard seed.

PLOT	WT. OF SEED	NO. OF PLANTS	WT. OF SEED PER 1000 PLANTS
Check	311.0 gm.	176	1767 gm.
Benzene hexachloride	681.4 gm.	230	2963 gm.
DDT	389.6 gm.	195	1998 gm.
Chlordan	455.6 gm.	265	1719 gm.

results are presented in table 6.

SUMMARY.—The incorporation into the soil of 27.5 pounds gamma of a technical benzene hexachloride containing 10 per cent of the gamma isomer gave practically 100 per cent control of the cabbage maggot, *Hylemya brassicae* (Bouché), on radishes, kohlrabi, broccoli, mustard and rutabaga throughout the 1947 growing season at Corvallis. A very high degree of control of the garden symphilid, Collembola and the larvae of the western spotted cucumber beetle was also indicated. The benzene hexachloride was rotary tilled into the top 7 to 8 inches of soil and was estimated to be at the rate of 1.010 pounds of the gamma isomer per 1000 cubic feet. The similar mixing into the soil of five other solid insecticides and the use of one soil fumigant gave no better control of the cabbage maggot than did the untreated checks. The incorporation of benzene hexachloride into the soil at rates up to 3.305 pounds per 1000 cubic feet with a garden rake gave fair protection to radishes for the first 39 days. These treatments failed, however, to give adequate protection beyond this length of time. Leaf mustard grown in the rotary tilled benzene hexachloride lot matured earlier and gave a substantially higher yield of seed than that grown in untreated soil and soil similarly treated with DDT and chlordan. The importance of deep, thorough mixing of the toxicant with the soil for control of the cabbage maggot has been indicated and is believed to be one of the most important developments of these experiments. Benzene hexachloride has shown very decided promise for cabbage maggot control when efficiently mixed with the soil. It has, however, certain disadvantages (phytotoxicity to certain plants and ability to flavor others) which may cause future limitations.

Additional experimental work with reduced dosages of benzene hexachloride and different methods of application may overcome these objections.

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Comparison of Toxic Actions of Chlordan, DDT, and Gamma-Benzene Hexachloride to the Southern Armyworm[1]

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It is known that DDT acts as a contact as well as a stomach poison, and that benzene hexachloride has fumigation, contact and stomach actions. The new synthetic insecticide, chlordan or 1,2,4,5,6,7,8,8-octachloro-4,7-methano-3a,4,7,7a-tetrahydroindane (Annand 1947) also shows both contact and stomach actions (Kearns *et al.* 1945: Weiman & Decker 1947). In many practical experiments the effects of fumigation, contact and stomach actions are not completely separable, and they are determined by testing against species of insects showing varying degrees of susceptibility to each action. It is the purpose of this study to compare the toxic effects of chlordan, DDT, and gamma-benzene hexachloride on the same insect species and to determine the effectiveness of each material as a fumigant, contact and stomach poison.

Larvae of the southern armyworm, *Prodenia eridania* (Cram.), were reared in the greenhouse on bean plants with potato tubers as a supplementary food when they were nearly full-grown. Since the larvae varied to a great extent in the rate of growth, age or instar is not accurate enough to indicate the size of larvae, and they were weighed. On the basis of equal weight of larvae in testing contact and fumigation actions, results appear to be more satisfactory. To avoid possible variations in the susceptibility of insects from day to day, all insecticides to be compared in fumigation and contact actions were tested on the same day. However, since tests on stomach action cannot be completed in one day, the results of the stomach poison action of the insecticides were obtained from experiments arranged at random and extended over a number of days.

FUMIGATION ACTION.—To compare the fumigation action of chlordan,[2] DDT,[3] and gamma-benzene hexachloride,[4] 10 g. of each material were spread over a large Petri dish in a desiccator. One day later, another smaller dish containing 10 larvae of equal size and a piece of potato was placed in the desiccator over the insecticide so that the larvae were in an atmosphere saturated with toxic vapor without opportunity for contact or stomach action. The desiccators were kept at 24° to 25° C. The humidity in the desiccator was very high, as shown by the condensation of water vapor. Mortality counts were made two days later. Those larvae with no signs of movement on prodding were considered as dead. Since all the tested materials gave very low mortalities on medium larvae (0.10 g. each), only results on small larvae (0.012 g. each) were listed in table 1. It was found that the fumigation action of chlordan (96.3 per cent mortality) was much stronger than either DDT (15.0 per cent mortality) or gamma-benzene hexachloride (35.0 per cent mortality).

Table 1.—Fumigation action on the southern armyworm of chlordan, DDT, and γ benzene hexachloride at saturated vapor at 24° to 25° C.

INSECTICIDE	TOTAL NUMBER OF SMALL LARVAE (0.012 G. EACH) IN 2 TO 4 TESTS	AVERAGE PER CENT MORTALITY 2 DAYS
Chlordan	80	96.3
γ-Benzene hexachloride	40	35.0
DDT	40	15.0
Check, untreated	60	0

CONTACT ACTION.—To eliminate the stomach and fumigation actions as much as possible, larvae were first dusted and then transferred to clean dishes with undusted food. All dusts were made by impregnating pyrophyllite[5] with an acetone solution of each insecticide so that distribution would be as uniform as possible. Another precaution was that the dust falling on the body of insects would have the same composition, as nearly as

[1] Research project supported by the Velsicol Corporation, Chicago, Illinois.

[2] Technical *Velsicol-1068*, Velsicol Corporation, Chicago, Illinois.

[3] Aerosol grade, setting point about 104° C., Hercules Powder Co., Wilmington, Delaware.

[4] Gamma isomer, m.p. about 110° C.

[5] *Pyrax ABB*, R. T. Vanderbilt Co., New York, N. Y.

possible, as the original dust. Because of the low percentage of toxicant in the dust, the usual method of settling dusts might separate the composition into different fractions. In order to avoid the possibility of segregation, various methods were studied to insure that all the materials discharged from the duster would be dispersed as fine dusts with a minimum of aggregates and deposited on the bottom of the tower without a preliminary settling period for eliminating larger particles as is often done. This was finally accomplished by discharging the dust from a special duster (Fig. 1) made from a condenser tube. As the compressed air (5 lb. per sq. in.) passed through the

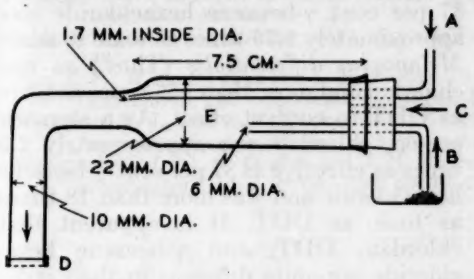

FIG. 1.—A laboratory duster for dispersing dusts from the top of a settling tower. A—compressed air; B—dust sucked in; C—air sucked in, to prevent eddy currents; and D—60-mesh wire gauze, to break the dust into fine powder.

upper tube, A, a suction was produced in the lower tube, B, and a weighed amount of dust was sucked up from the dish into the duster and blown out of the other end into the settling tower. A hole, C, which opened into the air chamber, E, served to prevent eddy currents in the duster. Without that hole about 50 per cent of the dust would be held back by the eddy current; with it only 5 to 10 per cent adhered to the glass wall. These were the results obtained for sticky dusts. For non-sticky dusts the amount of dust retained was much smaller. As soon as the dust came out of the duster, it struck a 60-mesh wire gauze, D, which broke the dust into fine powder. The time of settling varied with the nature of the dust. Usually a few minutes were enough for sticky dusts. By observation as well as by weighing a fairly uniform deposit was obtained. The amount of deposit of each dust was adjusted as close as possible to an average value of 0.53 mg. of dust per square centimeter. Immediately after dusting, the larvae were removed to clean open dishes containing untreated food for further observation. It was found that at one per cent concentration, all dusts but nicotine alkaloid were very effective against medium larvae (0.10 g. each) (Sun *et al.* 1948). However, to large larvae (0.70 g. each) DDT and γ-benzene hexachloride were more toxic than chlordan in contact action (Table 2).

Table 2.—Contact action on large larvae (0.70 g. each) of the southern armyworm of chlordan, DDT, γ-benzene hexachloride, and nicotine.

TOXICANT, APPLIED AS IMPREGNATED DUSTS CONTAINING 1 PER CENT OF INSECTICIDE ON PYROPHYLLITE	DEPOSIT OF 1 PER CENT DUST, MG. PER SQ. CM.	NUMBER OF LARVAE IN 5 TESTS	AVERAGE PER CENT MORTALITY 2 DAYS
Chordan	0.55	50	2
DDT	0.53	50	40
γ-Benzene hexachloride	0.58	50	32
Check, untreated		50	0

STOMACH ACTION.—To eliminate the contact action of insecticides, the inlay sandwich method with predetermined doses (Bulger 1937) was used with some minor changes. Because of the sticky nature of DDT and the high viscosity of chlordan, they cannot be applied in pure form by the method of settling dust or mist as often used in the sandwich method or contact sprays. A concentrated acetone solution of chlordan (1:1), DDT or γ-benzene hexachloride (both at 40 g. per 100 ml. acetone) was sprayed upward into a settling tower, as generally used for settling mist sprays. Instead of depositing as a solution, the insecticide after the evaporation of acetone was deposited directly on leaf discs as pure material. The amount of deposit was weighed on a large tin dish. Shrinkage of leaf discs was prevented by keeping them over wetted papers. By using three different deposits and three to four sizes of bean leaf discs, predetermined doses could be obtained for larvae weighing from 0.50 to 0.80 g. with an allowance of variation of ±0.01 g. from the calculated larval weight. After ingesting the whole sandwich, the larvae were kept at 24 to 25° C. in separate dishes for 4 days. Twenty-five larvae were used for each point in the curves. There was no trouble in feeding the last instar larvae, wtih sandwiches containing chlordan, DDT, or γ-benzene hexachloride, but about half of them refused to eat the whole sandwich as made from lead arse-

nate, even when the areas of those sandwiches were much smaller. It was found by plotting on log-probit scales (Bliss 1934) that the median lethal dose is 0.031 mg. per g. of body weight for γ-benzene hexachloride, 0.060 mg. for DDT, 0.13 mg. for chlordan, and 0.29 mg. for lead arsenate (Table 3). The mortality

Table 3.—Median lethal doses (LD-50) of chlordan, DDT, γ-benzene hexachloride, and lead arsenate for large larvae of the southern armyworm, by sandwich method.

Insecticide	LD 50 Mg. per g. Body Weight
Chlordan	0.13
DDT	0.060
γ-Benzene hexachloride	0.031
Lead arsenate	0.29

curves of larvae are shown in figure 2. On the basis of LD-50 values, chlordan, DDT, and γ-benzene hexachloride are 2.2, 4.8, and 9.4 times respectively more toxic than lead arsenate.

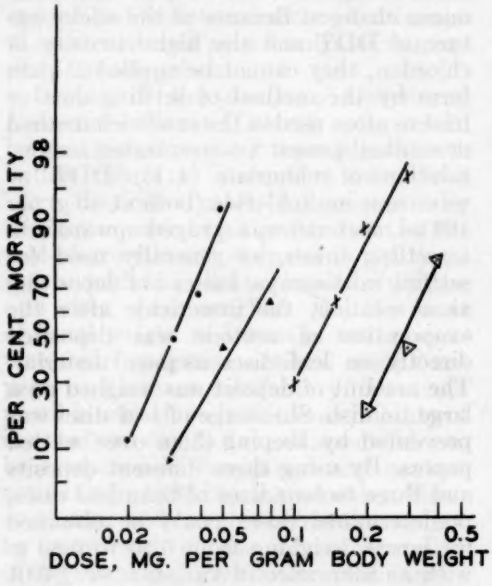

Fig. 2.—Toxicity curves of γ-benzene hexachloride. DDT, chlordan, and lead arsenate applied as stomach poisons to larvae of the southern armyworm (sandwich method); plotted on log-probit scales. ●=Benzene Hexachloride; ▲=DDT; ×=chlordan; △=Lead arsenate.

Conclusion and Discussion.—From the above results on fumigation, contact and stomach actions of these insecticides, it appears that chlordan is strongest in fumigation action at saturated vapor; DDT is most effective as a contact insecticide; γ-benzene hexachloride is most toxic as a stomach poison; and nicotine alkaloid and lead arsenate are much less toxic than these synthetic insecticides by the modes of application tested so far as the laboratory test on larvae of the southern armyworm is concerned. The relative order of their effectiveness may be arranged as follows:

Fumigation action: Chlordan>γ-benzene hexachloride>DDT
Contact action: DDT>γ-benzene hexachloride >chlordan>nicotine
Stomach action: γ-benzene hexachloride>DDT >chlordan>lead arsenate

Weinman & Decker (1947) found that 37 per cent γ-benzene hexachloride was approximately 1.75 times as toxic to adult *Melanoplus differentialis* (Thos.) as was chlordan and more than 136 times as toxic as DDT in contact effect. As a stomach poison, chlordan was approximately 2.5 times as effective as 37 per cent γ-benzene hexachloride and was more than 18 times as toxic as DDT. It is apparent that chlordan, DDT, and γ-benzene hexachloride are quite different in their order of toxicity, either as contact or stomach poison, against the southern armyworm and grasshoppers. It is beyond doubt that chlordan is more effective than DDT and in some cases more effective than benzene hexachloride against grasshoppers, *M. differentialis* (Thos.) and *M. femur-rubrum* (Deg.) (Weinman & Decker 1947, Weinman *et al.* 1947, List & Hoerner 1947, Sun *et al.* 1948). The specificity in toxicity of chlordan was also shown by Eide (1947) in testing a number of insecticides against honeybees. He found that chlordan was in the group of insecticides which were non-toxic to honeybees at the tested concentrations, while DDT and benzene hexachloride were highly toxic. This would be counted as an advantage for chlordan when used in the blossom period.

Summary.—The fumigation, contact and stomach actions of chlordan, DDT and γ-benzene hexachloride were tested on larvae of the southern armyworm *Prodenia eridania* (Cram.), It was found that chlordan is strongest in fumigation action at saturated vapor; DDT is most effective as a contact insecticide; γ-benzene hexachloride is most toxic as a stomach poison; and nicotine and lead arsenate

are much less toxic than these chlorinated hydrocarbons when used as contact and stomach insecticides respectively.

A special duster was designed for applying sticky dusts with only a few per cent of toxicant. By discharging dusts from the top of a settling tower and by collecting dusts without a preliminary settling period, the deposit would contain a concentration of insecticide more close to that in the original dust mixture.

A method of obtaining an accurate deposit of pure sticky solid or thick liquid insecticides, such as DDT and chlordan, for a sandwich method was obtained by spraying upward a proper concentration of insecticide in acetone solution into a settling tower, as generally used for settling mist sprays. Instead of depositing as a solution the insecticide after the evaporation of acetone was deposited directly on leaves as pure material.

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Compounds More Toxic Than DDT to Body Lice[1]

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From 1942 to 1946 a total of 7019 organic compounds were tested at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine to determine their toxicity to body lice, *Pediculus humanus corporis* Deg. Further study of the 284 most promising compounds revealed that 5 of them were more toxic than DDT. Comparative tests of these compounds with DDT are described in this article.

MATERIALS.—The following insecticides were used: DDT (purified); 2-pivalyl-1,3-indandione; chlordan (technical); chlorinated camphene; and two forms of benzene hexachloride, the crude form containing 10 per cent of the gamma isomer and a product consisting chiefly of the gamma isomer.

BEAKER TESTS.—A modification of the beaker test method used for evaluating materials as toxicants for body lice (Bushland *et al.* 1944) was employed to evaluate the test materials. The compounds were dissolved in acetone to make solutions of the desired strength. Disks of woolen cloth, of the same diameter as a 50-ml. beaker, were saturated with the test solutions and then suspended on pins to dry for about 2 hours at room temperature. The pieces of cloth took up an amount of liquid almost equal to their dry weight, so that the concentration of insecticide in an impregnated cloth was about the same as that in the solution.

The impregnated disks were placed in 50-ml. beakers, and 10 young adult body lice were placed on each disk. The beakers were held at a temperature of $30 \pm 2°$ C. and a relative humidity of approximately 85 per cent for 24 hours, and then removed for examination.

In earlier tests, pads impregnated with 0.05 per cent solutions of the various materials were lethal, killing all lice within

[1] This research was conducted as part of a program supported by transfer of funds from the Office of the Surgeon General, U. S. Army, to the Bureau of Entomology and Plant Quarantine.

[2] A. B. Anderson assisted with the tests, and G. H. Culpepper reared the lice used in the studies. F. H. Babers and Helen Fluno prepared certain formulations for testing.

24 hours. The same results were obtained in this study with a series of cloths treated with 0.05 per cent solutions. Further comparisons were made by treating cloths with solutions containing 0.005, 0.0025, 0.001, 0.0005, and 0.00025 per cent of the insecticides. All treated cloths were tested simultaneously.

The experiment was replicated three times, different sets of impregnated cloths and different lots of body lice being used each time. There were insufficient insects to test all the cloths in the third replication; so the 0.00025 per cent solution was tested against only 20 lice. The results of the tests are summarized in table 1.

DDT and 2-pivalyl-1,3-indandione were the least toxic materials, since some of the survivors at a concentration of 0.005 per cent apparently were normal. Crude benzene hexachloride and chlorinated camphene were effective at concentrations of 0.005 and 0.0025 per cent, but did not kill or adversely affect all lice at 0.001 per cent. The crude benzene hexachloride appeared to be somewhat more toxic than the chlorinated camphene. Gamma-benzene hexachloride and chlordan were most toxic to lice, since they allowed no normal survivors at four of the five concentrations tested.

SPEED OF TOXIC ACTION.—Eddy & Carson (1946) described the beaker test method of measuring the knock-down caused by compounds toxic to body lice, and gave results of tests on certain of the materials considered in the present study. The procedure consisted in placing 10 lice each on pads impregnated with 1 per cent of insecticide, holding the beakers at 30° C., and making observations after 15 and 30 minutes and after 1, 3, and 6 hours. When none of the insects could walk or cling to the pads, that interval was noted as the knock-down time.

2-Pivalyl-1,3-indandione and both forms of benzene hexachloride caused paralysis within 15 minutes. Most of the insects exposed to chlordan were paralyzed within an hour, but it was not until the 3-hour examination that all of them were found knocked down. Chlorinated camphene caused knock-down in 5 hours and DDT required 6 hours.

ARM-AND-LEG TESTS OF INSECTICIDES IN POWDER FORM.—The materials were tested as powders at various concentrations by the arm-and-leg method described by Bushland *et al.* (1944). The desired insecticide was dissolved in acetone and then mixed with pyrophyllite to make a paste. The acetone was evaporated at room temperature and the mixture reground on a glass plate to a fine powder. Sleeves made of winter-weight cotton-underwear cloth were treated by spreading 3 grams of the test powder evenly over the inner surface of the garment and rubbing it lightly into the fabric with the fingers. The treated sleeves were placed on the arms and legs of research subjects, and 25 young adult body lice were confined in each sleeve, which was fastened to the skin with adhesive tape. After 24 and 48 hours the sleeves were removed for examination. By this method four materials could be tested simultaneously on one man.

(a) *Tests with Low Concentrations.*—To observe the effects of low concentrations, two replications were made with powders containing 0.05, 0.01, and 0.005 per cent of the insecticide. Lice were confined in the treated sleeves for 24 hours. The results are shown in table 2.

All the materials except DDT were effective as 0.05 per cent powders. The γ-benzene hexachloride was the only one

Table 1.—Results of beaker tests showing percentages of lice that were affected[1] and dead after 24 hours' exposure on cloths impregnated with various concentrations of different insecticides. (3 replications.)

INSECTICIDE	0.005%		0.0025%		0.001%		0.005%		0.00025%[2]	
	Affected	Dead	Affected	Dead	Affected	Dead	Affected	Dead	Affected	Dead
DDT	30	50	37	20	23	7	20	0	0	0
Crude benzene hexachloride (gamma isomer 10 per cent)	37	63	50	50	60	23	67	0	30	5
γ-benzene hexachloride	10	90	10	90	43	57	37	63	25	0
Chlorinated camphene	33	67	70	30	60	10	37	3	5	0
2-Pivalyl-1,3-indandione	40	47	23	7	23	0	0	0	0	0
Chlordan (technical)	33	67	40	60	73	27	77	23	80	0

[1] Lice able to crawl but not with complete coordination of body movements.
[2] Only 2 replications.

Table 2.—Average per cent mortality of body lice confined for 24 hours in treated sleeves in arm-and-leg tests of powders containing low concentrations of insecticide.

INSECTICIDE	0.05%[1]	0.01%[2]	0.005%[2]
DDT	60	26	—
Crude benzene hexachloride (gamma isomer 10 per cent)	100	67	36
γ-Benzene hexachloride	100	90[3]	86
Chlorinated camphene	99[3]	39	—
2-Pivalyl-1,3-indandione	100	57	—
Chlordan (technical)	98[3]	64	38

[1] 4 tests.
[2] 8 tests.
[3] None of the surviving lice was of normal vigor.

that killed or adversely affected all the lice at a concentration of 0.01 per cent. DDT was almost entirely ineffective at this concentration.

No untreated checks were used in this series of tests, but they were used periodically throughout the arm-and-leg studies. The mortality in untreated sleeves was usually less than 20 per cent.

(b) *Tests with High Concentrations.*—Since the new insecticides were more effective than DDT at very low concentrations, tests were also made at higher concentrations to compare the persistence of toxic action with that of DDT. Powders containing 1 and 5 per cent of the different materials were tested in quadruplicate by the arm-and-leg method. The treated sleeves were worn by research subjects for 4 days, and then the first lice were introduced. The sleeves were removed for examination after 48 hours and new lice were introduced. This procedure was repeated until the treatments allowed several normal survivors.

At the 1 per cent concentration chlorinated camphene, 2-pivalyl-1,3-indandione, and chlordan were almost 100 per cent effective against lice introduced into sleeves 12 days after being treated with these materials, and these materials were, respectively, 94, 84, and 82 per cent effective after 14 days. DDT was 95 per cent effective after 12 days, crude benzene hexachloride was 90 per cent after 6 days, and gamma-benzene hexachloride 86 per cent after 8 days.

At the 5 per cent concentration, crude benzene hexachloride was the first treatment to show signs of failure, killing only 89 per cent of the lice introduced on the sixth day. The gamma isomer was effective on the sixth day, but caused only 88 per cent mortality of lice introduced when the sleeves had been worn 8 days. The other treatments caused approximately 100 per cent mortality through 22 days wearing. After 28 days chlorinated camphene was 99 per cent effective, and DDT, 2-pivalyl-1,3-indandione, and chlordan were 93, 70, and 89 per cent effective, respectively.

In another series of quadruplicate tests with 5 per cent powders, the treated sleeves were worn for 14 days instead of 4 days before lice were introduced. Crude benzene hexachloride failed on the 16th day, killing only 92 per cent of the lice introduced at that time. The gamma isomer killed 90 per cent of the lice introduced on the 18th day and only 75 per cent of those placed in the sleeves on the 20th day. 2-Pivalyl-1,3-indandione killed all the lice up to the 24th day, and mortalities on the twenty-fourth, twenty-sixth, and twenty-eighth days were 97, 99, and 91 per cent. DDT, chlordan, and chlorinated camphene were 100 per cent lethal throughout the test, which was terminated after 30 days. The greater persistence of the compounds in this series may have been due to the length of time the sleeves were worn before the lice were introduced. In the earlier tests there was some mechanical loss of powder through removal of the sleeves for each 48-hour examination, and this may have accounted for the failure of the sleeves which were infested from the fourth day of wearing.

Neither form of benzene hexachloride was sufficiently persistent to rank with DDT as a toxicant for louse powders. At the 1 and 5 per cent concentrations all the other insecticides were as effective as DDT. At these concentrations the tests were not sufficiently extensive, nor were the differences great enough to warrant definite conclusions as to which material performed best. Ten per cent powders were not compared, because the 5 per cent treatments lasted as long as it was practical to continue observations.

LAUNDERING TESTS WITH IMPREGNATED SLEEVES.—Jones *et al.* (1945) found that underwear impregnated with 1 per cent of DDT remained lethal to lice after four launderings and that higher concentrations were effective for even a greater

number of launderings. Since this was true with DDT-impregnated underwear it was considered worthwhile to test the effectiveness of impregnations with the new toxicants.

The sleeves of underwear cloth regularly used for arm-and-leg tests were impregnated with 60 ml. each of a 1 per cent acetone solution of test material. The deposit of insecticide was about 2 per cent of the dry weight of the sleeve. The sleeves were allowed to dry at room temperature for a day or longer and were then laundered.

Laundering consisted of placing the sleeves in a boiling solution of 1 per cent army-issue laundry soap and boiling them for 15 minutes. The sleeves were then removed and rinsed through four changes of cold water. Sleeves treated with each insecticide were boiled and rinsed as separate groups. The number of sleeves boiled at one time varied, but for each sleeve the same amount of soap solution (375 ml.) was used.

After the sleeves were washed they were dried at room temperature and then placed on research subjects and infested with 25 lice each. The sleeves were removed after 48 hours for examination and those that were effective were subjected to repeated launderings until the treatments failed.

Two sets of tests were made in which all the insecticides were compared directly in duplicate. As the results in both replications were similar the data have been combined.

2-Pivalyl-1,3-indandione killed only 64 per cent of the lice after a single laundering, and neither form of benzene hexachloride withstood two boilings. Chlordan seemed to be less resistant to boiling than DDT, and chlorinated camphene appeared more resistant, but further tests were necessary before definite conclusions could be made. Therefore, four sleeves were treated with each of the three laundry-resistant insecticides, DDT, chlordan, and the chlorinated camphene, subjected to three launderings and dryings as outlined above, and then placed on research subjects in the same manner as was described for the preliminary series. Both DDT and chlordan performed somewhat better than in the previous tests. This may have been due to the difference in the conditions of the tests.

Despite the variability in results it seemed definite that chlordan was less resistant to laundering than were DDT and chlorinated camphene. The last two materials were further compared by impregnating six sleeves with each material. The results did not differ greatly among themselves or from those of previous tests. In general chlorinated camphene was slightly more effective than DDT. DDT impregnations were replicated four times, and in three of the replications the treatment allowed some apparently normal lice to survive in sleeves laundered four times. In all these tests chlorinated camphene was compared directly with DDT, and it allowed no normal survivors after four launderings.

Kearns *et al.* (1945, p. 661) stated that chlordan (1068) should be considered incompatible with materials having an alkaline reaction because "Like DDT and gamma-benzene hexachloride (chlordan) has the property of dehydrohalogenating readily in the presence of weak alkali to form a product which apparently is nontoxic to insects." The 1 per cent soap solution used in the laundering tests was found to have a pH of 9.3. The marked resistance of DDT and chlorinated camphene to the laundry process indicates that for some purposes these materials might be compatible with diluents that are somewhat alkaline.

OVICIDAL EFFECTS.—2-Pivalyl-1,3-indandione, which caused complete mortality of louse eggs in all stages of incubation when applied as a 0.5 per cent solution (Eddy & Carson 1947), is the only material in the group that is outstanding as an ovicide. In screening tests (U. S. Bur. Ent. and Plant Quar. 1947.) gamma-benzene hexachloride was ovicidal as a 5 per cent solution, but not at lower concentrations. DDT, crude benzene hexachloride, chlorinated camphene, and chlordan were ineffective at the highest concentrations tested.

DISCUSSION.—The beaker tests summarized in table 1 indicated that, when used to impregnate cloth in low concentrations, all the compounds except 2-pivalyl-1,3-indandione were more toxic to body lice than was DDT. In these tests the two materials produced similar results.

The arm-and-leg tests with dilute powders showed that in this form all the insec-

ticides were more toxic than DDT. At concentrations of 1 and 5 per cent both forms of benzene hexachloride were not sufficiently persistent to rank with DDT as practical louse powders, but the chlorinated camphene, 2-pivalyl-1,3-indandione, and chlordan gave results similar to those obtained with DDT.

2-Pivalyl-1,3-indandione failed to withstand a single boiling when applied to arm-and-leg sleeves in amounts equivalent to about 2 per cent of the weight of the cloth and tested for resistance to laundering. Both forms of benzene hexachloride were ineffective after the garments had been boiled twice. Chlordan was less effective than DDT, but chlorinated camphene seemed more resistant to boiling. Chlorinated camphene was consistently lethal after four launderings.

2-Pivalyl-1,3-indandione probably cannot be used for body louse control, because the U. S. Food and Drug Administration considers it unsafe for use on human skin, except at very low concentrations.

The lack of persistence and the objectionable odor of benzene hexachloride make this material inferior to DDT for practical louse control.

Chlordan kills lice about twice as fast as DDT or chlorinated camphene. When impregnated in underwear, chlorinated camphene was more effective than DDT. Preliminary investigations, however, indicate that these materials are toxic to humans when used at the usual strengths. Therefore, further research to determine the degree of hazard is necessary before they can be recommended for use.

SUMMARY.—Five new organic insecticides were tested by various established laboratory procedures in direct comparison with DDT against the body louse, *Pediculus humanus corporis* Deg. When the materials were applied to cloth and evaluated by the beaker test method, the most toxic were gamma-benzene hexachloride and technical chlordan. Both these materials were effective at a concentration of 0.0005 per cent. Chlorinated camphene and crude benzene hexachloride were effective at 0.0025 per cent, whereas DDT and 2-pivalyl-1,3-indandione did not adversely affect all the test insects at 0.005 per cent. Lice exposed on cloths impregnated with 1 per cent of insecticide were paralyzed within 15 minutes by crude and gamma-benzene hexachloride and 2-pivalyl-1,3-indandione. Chlordan immobilized the lice within 3 hours, but chlorinated camphene required 5 hours and DDT 6 hours.

In arm-and-leg tests DDT was ineffective as a 0.05 per cent powder, but the other materials were lethal at that concentration. Only γ-benzene hexachloride was effective at 0.01 per cent. As 1 and 5 per cent powders, both forms of benzene hexachloride lost their insecticidal effect much more rapidly than the other materials. 2-Pivalyl-1,3-indandione, chlorinated camphene, and chlordan were about as long-lasting as DDT.

Sleeves of cotton underwear cloth impregnated with 2 per cent of the insecticides were compared for resistance to laundering. Chlorinated camphene, which was the most effective treatment, remained lethal to lice after four 15-minute boilings in a 1 per cent soap solution. DDT lasted almost as long, and was superior to chlordan. Crude and γ-benzene hexachloride withstood only one boiling, whereas 2-pivalyl-1,3-indandione was rendered ineffective by one laundering.

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The Effects of Certain New Soil Insecticides on Plants[1]

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Heavy concentrations of insecticides, when incorporated in soil for control of various soil pests, have frequently resulted in plant injury. Heavy dosages of lead arsenate have been used safely in turf for control of Japanese beetle larvae in eastern United States. Accumulations of lead arsenate in the soil of Pacific Northwest orchards over a period of years have, however, resulted in the development of conditions which are toxic to plant life.

The recent development of DDT and other new insecticides has stimulated interest in their use for control of various soil pests. Some information on the phytotoxicity of these materials has already been published. Morrison *et al.* (1945a and 1945b) reported that DDT used as a seed treatment on beans and carrots delayed germination but did not impair growth. In an unpublished report, Morrison (1945c) stated that 20 per cent DDT mixed with beet seed at the rate of 0.5 lbs. per pound of seed did not impair growth of beets. Both 50 per cent wettable DDT and 20 per cent benzene hexachloride at the same rates destroyed all beet plants. The percentage of gamma isomer was not known.

He also reported (1945c) on the effects of DDT mixed with soil at the rate of 428 parts per million in greenhouse tests. Tomatoes and beans were severely stunted but lettuce and cabbage were significantly more vigorous than the controls. This was evident in both steam sterilized and unsterilized soil. The use of a balanced fertilizer 5-7-8 (mixtures of muriate of potash and ammonium phosphate) with DDT in the soil injured all plants and greatly accentuated the injury of tomatoes and beans. The inclusion of manure with DDT in the soil did not modify results. A repeated planting in the original soil gave results which closely paralleled those of the first planting.

Wilson & Choudri (1946) carried on studies with heavy concentrations of DDT in soil and found no adverse effects on soil microorganisms. Ammonification, nitrate accumulation and salt concentration were not seriously modified. McLeod (1946a) found that field tests with hexachlorocyclohexane gave excellent control of the onion maggot but soil treatments with this material severely injured onions. He (1946b) later observed that amounts of 20 per cent benzene hexachloride (gamma isomer content not revealed) in excess of 0.5 lbs. per 2 pounds of soil produced decided toxicity to onions. Concentrations below this amount did not produce injury.

Fulton (1946) found benzene hexachloride was efficient in control of the southern corn rootworm. No injury to corn was noted in one experiment but in another test the material caused decided injury. The differences between the two experiments were the seed used, soil type and probably soil temperature.

Fleming & Maines (1947) reported on results with technical grade DDT in 28 different soil types against larvae of the Japanese beetle. They observed that soil type or soil minerals may have influenced the rate of kill of the beetle larvae. Fleming (1947) listed 17 vegetables, 17 cereals and grasses and 248 ornamentals which were not adversely affected by DDT in the soil. 5 vegetables and 5 ornamentals were listed as definitely stunted by DDT in the soil. There was evidence that some vegetables did not tolerate 25 pounds of technical DDT per acre but grew normally in soil containing 200 pounds of purified DDT per acre.

Grayson & Poos (1947) applied DDT (200 lbs. per acre) and benzene hexachloride (30 lbs. gamma isomer per acre) at a depth of 1.5 to 2 inches. No injury was noted in DDT treated soil but injury to corn, peanuts, cotton and soybeans was observed in the benzene hexachloride treatments. Cotton, soybeans and peanuts were more tolerant than corn to benzene hexachloride in the soil.

A series of experimental plots were laid out in the spring of 1947 on an area of 1.13 acres at the Entomology farm in Corvallis, Oregon. The soil type of this land is classified as cove clay. It is of colluvial origin, quite heavy in texture and fairly impervious to water. Drainage is poor and thes oil very difficult to work.

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It is, however, high in organic matter and quite productive.

This plot of soil was manured heavily in the spring of 1947 and tilled twice with a rotary tiller on May 4. The tiller covered a six foot swath and was powered with a 100 H.P. auxiliary gasoline engine.

One plot was treated with propylene dichloride on May 5 with a power weed and soil fumigator. The remaining plots were treated with dry powders on May 18 with a 3 foot hand fertilizer spreader. All plots were again tilled with the rotary tiller May 18 to a depth of 7 to 8 inches.

Some difficulty was experienced in applying dry chemicals through the applicator because differences in diluent and stickiness of the active ingredient influenced the rate of flow. Amounts of active ingredient per acre are therefore not strictly comparable. The application of small quantities of toxicants per acre is likely to present a problem in the treatment of large areas. Table 1 designates the treatments used.

Table 1.—Soil treatments at Corvallis, Oregon, 1947.

MATERIALS	POUNDS ACTUAL INGREDIENT PER ACRE	ESTIMATED CONCENTRATION IN SOIL—POUNDS PER 1000 CU FT.[1]
Dichloro-diphenyldichloroethane (5% wettable)	106.8	3.922
Hydroxypentamethylflaven (30% concentrate)	38.4	1.410
DDT (50% wettable)	137.5	4.701
Benzenehexachloride (Technical grade 10% gamma isomer content)	27.5 (gamma)	1.010 (gamma)
Chlordan (5% dust in talc)	27.5	1.010
Chlorinated Camphene. 5% dust	27.5	1.010
Propylenedichloride	288.0	—

[1] Rate per 1000 cu. ft. was computed on the assumption that rotary tillage provided uniform distribution of the toxicant in the soil.

Check or untreated plots were allowed to stand between each treated plot for direct comparisons. There were no replications of treated plots. A total of 29 different vegetables were planted across and at right angles to the treated and check plots. Most plants were grown from seed but in some instances additional plantings of tomatoes, lettuce, peppers and eggplant were planted from transplants. Most vegetable seeds were planted May 20 with several additional rows of corn planted on May 27. Prolonged rains prevented germination of the first bean planting of May 31 and these were replanted on June 11.

A supplement to this experiment was laid out at Eugene, Oregon, on May 15, on soil classified as Chehalis fine sandy loam. One tenth acre plots of chlordane, 1,1-x-chlorodiphenyl ethane, chlorinated camphene and dichloro diphenyl ethane at the rate of 10 pounds per acre were compared with benzene hexachloride at the rate of 10 pounds gamma isomer per acre. Materials were applied with the fertilizer applicator and rotary tilled to a depth of 3 to 4 inches. The active ingredients were accordingly applied at the rate of 0.787 lbs. per 1000 cu. ft. There were no replications of treatments and 0.1 acre check plots were arranged beside each treated plot. Beans (Variety Blue Lake) were planted in both treated and check plots.

RESULTS.—Observations were made throughout the season on the effects of treatments on plant growth and control of various soil arthropods. Results on control of the latter will be treated in another paper.

Propylene dichloride. 15 days were allowed to elapse between time of treatment and date of planting. There was no evidence of plant injury from this material.

Dichloro-diphenyl dichloroethane, hydroxypentamethyl flavan and chlorinated camphene did not give any evidence of plant injury.

Chlordan produced slight stunting and chlorosis of lima beans at Corvallis.

DDT, as used, caused severe stunting to bush and pole beans at Corvallis. Tomato transplants were slightly stunted and were characterized by small leaves and fruit.

Benzene hexachloride at rate of 10 pounds gamma isomer per acre (0.787 lbs. per 1000 cubic feet) caused no injury at Eugene. Bean plants were quite vigorous throughout the season. However, benzene hexachloride at Corvallis at the rate of 27.5 lbs. gamma isomer per acre (1.010 lbs. per 1000 cu. ft.) caused a

varied degree of plant injury. Injury may be classified as follows:

Vegetables Totally Destroyed

Crops	*Variety*
Beets	Detroit Dark Red
Cantaloupe	Hales Best
Chard	Giant Lucullus
Corn	Hummer and Golden Cross Bantam
Cucumbers	Boston Pickling
Onions	White Bermuda
Peas	Blue Bantam
Peppers from Seed	California Wonder
Potatoes	White Rose
Pumpkin	Pie
Spinach	Nobel Giant
Squash	Table Queen and Summer Crookneck
Tampala	
Tomato from Seed	Bonny Best
Watermelon	Klondike

Vegetables Partially Susceptible

Beans, bush	Burpee Stringless Bush
Beans, pole	Rogers (Blue Lake) and Associated 12 (Blue Lake)
Beans, lima	Burpee Bush Lima
Endive	Green Curled
Lettuce from Seed	Grand Rapids
Lettuce Sets	New York Head
Pepper Sets	California Wonder
Tomato Sets	Chatham, Golden Jubilee, Pritchard, Bonny Best and Stokesdale

Vegetables Not Injured

Broccoli	Italian
Cabbage	Golden Acre
Carrots	Chatennay
Celery Sets	Utah Green
Kohlrabi	Early Purple
Mustard	Southern Curled
Parsnips	Hollow Crown
Radish	Crimson Giant
Rutabaga	

Definite control was accomplished with benzene hexachloride on such weeds as lambs quarter, *Chenopodium album* Linn., pigweed, *Amaranthus retroflexus* Linn., and bindweed, *Convolvulus arvensis* Linn., in the Corvallis experiment. The control of these weeds lasted for over 5 months. There was no apparent effect of benzene hexachloride on any of the grasses or on common groundsel, *Senecio vulgaris* Linn. The latter weed appeared to flourish. However, it required 5 months to produce seed and its apparent abundance may have been due to lack of competition with other weeds.

Germination of some plants such as lambs quarter, pigweed, potatoes, corn, curcubits and peas was not apparently impaired by benzene hexachloride. These plants grew to the seedling stage, then became stunted and finally died. Roots of the stunted plants were characterized by a dark brown color.

Pepper and tomato seeds were killed by benzene hexachloride but transplants of these vegetables withstood the treatment to some degree. Tomato transplants were severely stunted and several died. Others recovered and produced a fair crop. Pepper transplants were not badly stunted but all fruit in the treated plot were erect and protruded above the top of the plant. This peculiarity became less noticeable as the plant matured.

Cruciferous plants exhibited decided increase in vigor in the benzene hexachloride treatment. It could not be ascertained whether this was associated directly with plant response or indirectly by pest control.

Eggplant (Black Beauty variety) was not included in the benzene hexachloride plot and information on its susceptibility to benzene hexachloride is not available.

Beans were stunted in the Corvallis benzene hexachloride plots and uninjured in benzene hexachloride treated soil at Eugene. There are a number of variable factors which are presented in table 2.

Table 2.—Variable factors between soil treatments at Corvallis and Eugene, Oregon.

	EUGENE	CORVALLIS
Method of Application	Fertilizer Applicator	Fertilizer Applicator
Rate of γ-benzene hexachloride	10.0 lbs. per acre	27.5 lbs. per acre
Tillage after Treatment	Rotary tilled to 3 to 4 inch depth	Rotary tilled to 7 to 8 inch depth
Rate Gamma Isomer per 1000 cu. ft.	0.787 lbs.	1.010 lbs.
Fertilizer Program	Side dressing ammonium phosphate	Manured
Soil Type	Chehalis fine sandy loam	Cove Clay
pH of Soil	6.8	6.5
Injury to Beans	None	Severe
Variety of Beans	Blue Lake	Two selections from Blue Lake and Burpee Stringless Bush.

Observations were made throughout the season for flavor which may have been imparted to vegetables grown in benzene hexachloride treated soil. The ability to detect this off flavor seemingly varies with the taste buds of the individual. The off flavor is not always immediately discernible but may develop 15 to 20 minutes later as an after taste.

No flavoring of benzene hexachloride could be detected in cabbage, broccoli, kohlrabi, mustard, celery, carrots, lettuce, endive, lima beans, tomatoes, peppers,

parsnips, bush beans and pole beans.

Nearly all of the potatoes in the benzene hexachloride plot was killed by the treatment but several plants grew and produced small tubers. These were definitely off flavor. Potatoes grown in another block were dusted with benzene hexachloride and these tubers also developed an off flavor. Most of the flavored potatoes in the dusted block were sunburned. This may indicate that the flavor was acquired by contamination of dust on the tuber.

One corn plant grew in the benzene hexachloride plot. It was considerably retarded but produced two normal ears. These ears were tasted uncooked. The benzene hexachloride flavor could be detected at the base of the ear but not at the tip. One block of corn was dusted three times with benzene hexachloride for corn earworm tests. Treatments started when silks were forming. The benzene hexachloride flavor was readily detected in the corn. The ears were well protected by husks and contamination could not have been accomplished by handling. Chemical analyses[1] of the treated corn failed to reveal any trace of organic chlorine, indicative of benzene hexachloride. O'Kane (1947) has reported on flavoring of certain vegetables with benzene hexachloride dusts.

DISCUSSION OF RESULTS.—Benzene hexachloride has shown decided promise as a soil insecticide against a number of troublesome soil pests. It is also decidedly toxic to a considerable number of vegetables. Other vegetables are moderately susceptible and still others are tolerant to a high degree. Certain crops, such as crucifers grow vigorously in benzene hexachloride treated soil. This may be due to direct plant response or be a measure of insect control.

Beans are seemingly fairly resistant to benzene hexachloride in soil. The difference in results which were obtained at Corvallis and Eugene are of interest. Differences in depth of tillage and mixing between the two experiments show that a difference of less than 4 ounces per 1000 cu. ft. of gamma isomer existed between the two locations. This reasoning is based on the assumption that rotary tillage provides uniform distribution of the toxicant with the soil. Additional work may prove this assumption incorrect, or dependent on physical properties of the soil. If the above assumption is correct, then injury to plants by benzene hexachloride must be associated with soil type, soil minerals, acidity or other factors.

Toxicity of benzene hexachloride to insects is generally credited to gamma isomer content, with the alpha isomer possessing some toxicity and the beta, epsilon and delta isomers having practically no toxicity (Metcalf 1947). The ability of benzene hexachloride to injure or flavor certain vegetables may be associated with any of these isomers. Crude benzene hexachloride generally contains from 10 to 12 per cent gamma isomer, but some proprietary products now have as high as 36 per cent gamma isomer. Additional work with known composition of all isomers of benzene hexachloride may give needed information of the safety of this material in the soil.

Toxicity to certain plants by benzene hexachloride in the soil is known to exist for at least 5 months when benzene hexachloride is mixed deeply in the soil. It is not yet known whether toxicity of benzene hexachloride or its ability to flavor certain vegetables will prevail longer than one season.

Additional information is needed on the immediate and prolonged toxicity of benzene hexachloride to plants, the immediate or prolonged tendency to flavor certain vegetables, and methods of application to the soil before the material can be accepted for pest control without strict regulation of crop rotation.

SUMMARY.—Twenty-nine different vegetables were planted in soils which were treated heavily with certain new insecticides. Heavy applications of DDT and chlordan caused some degree of plant injury. Benzene hexachloride at the rate of 1.010 lbs. gamma isomer per 1000 cu. ft. caused varying degrees of plant injury and flavored certain vegetables. This material has shown decided promise for control of various soil pests but lack of information on its disadvantages greatly limits its immediate acceptance.—11-16-47.

[1] Chemical analyses were made by R. H. Robinson, Agricultural Chemist, Oregon State College.

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Field Studies on Control of Onion Thrips in New York

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Until the advent of DDT, the chief control of the onion thrips, *Thrips tabaci* Lind., was the use of sprays containing tartar emetic. A paper by Ewart *et al.* (1944) fully reviewed the uses of this toxicant and described experiments conducted on New York mucklands on which those described in this paper were also conducted. DDT afforded a new and more effective toxicant, and this material has been widely investigated throughout the country.

The work of Smith as reported by Annand (1944) was apparently the first in which DDT was used in tests against the onion thrips. Promising control was obtained with DDT but the tarter emetic-sugar-water treatment resulted in significantly higher yields than did any other treatment. Tests by Smith & Goodhue (1945) resulted in excellent control of thrips on onions in the greenhouse. Jepson & Borden (1945) obtained no significant yield differences between treatments of DDT in aerosol, spray and dust formulations, but yields due to the use of this toxicant were 7000–8700 pounds per acre more than those with nicotine treatment in any form with which they were compared. Sleesman (1946) reported high degrees of control of onion thrips, and corresponding increases in yields, in DDT-treated plots on muck-grown onions in Ohio. Although sprays gave better control than did a dust of comparable amount of toxic ingredient, yields were about the same in dusted and sprayed plots. Hibbs & Ewart (1946) found that the addition of sulphur to DDT dusts resulted in increased thrips control and higher yields in Texas. Peay and Sorenson (1946) found that DDT in sprays gave a high degree of thrips control and increased yields of onion seed. Numerous other workers throughout the country have tested DDT in spray, dust and aerosol formulations, and in general have indicated its superiority to other materials for thrips control.

During the past several years some 15 experiments, involving more than 40 acres of experimental plots have been conducted on New York mucklands. In them DDT has been tested in sprays, dusts, aerosols, different grinds, various concentrations, and in schedules with different starting and stopping dates as well as with various intervals between applications. Details of these tests are omitted from the present writing. Other tests have been conducted with fungicide additions to DDT, and with sulphur and other insecticides included in dust or aerosol formulations. In most instances thrips populations have been so low that individual experiments have not been outstanding either as to thrips reductions or yield increases. However, certain of these tests have produced results which have been interesting and applicable in the formulation of a dusting program, and which have substantiated the value of DDT for thrips control under conditions of heavy infestation.

In general there seemed to be little value received from applications of DDT

made early in the season before thrips populations had built up appreciably. Residual toxicity seemed to be definitely limited under field conditions, indicating the necessity for rather frequent applications at times when thrips were building up to damaging levels. Applications of DDT in sprays were not superior to dust formulations under the conditions of these experiments.

RESIDUE STUDIES.[1]—When early toxicity studies indicated that DDT was a promising toxicant for onion thrips control, preliminary residue analyses were made to measure amounts of the toxicant remaining on and in harvested bulbs of onions which had been treated with DDT dusts and sprays. Very slight residues were indicated in these early tests, so field studies on commercial plantings were made during the summer of 1946. Residue analyses were conducted on bulbs harvested from the plots treated with various formulations, concentrations and numbers of applications of DDT dusts and sprays. Since the early studies had indicated that no DDT was absorbed or otherwise present in the bulb, onions receiving applications in the field were cured for several weeks and then the outer scales only were employed for analyses. Although some plots from which samples were analyzed received as much as 5.25 pounds of DDT per acre per season in dust applications, or 4 pounds in spray applications, there were no DDT residues in excess of 0.2 p.p.m. on harvested bulbs. It was thus quite evident that onions so treated for insect control hardly constitute a source of DDT in amounts dangerous to consumers.

DDT WITH FUNGICIDES.—An experiment of particular interest was one in which DDT-fungicide dusts were applied to non-replicated acre beds by airplane for thrips control and control of onion mildew caused by *Peronospora destructor* (Berk.). Dust formulations of 3 per cent DDT, with each of two different fungicides[2] and a formulation containing 3 per cent DDT alone were compared. Two or three applications of each material were made at two-week intervals by fixed-wing plane at a rate of 50 pounds per acre per application. Thrips populations were determined in a leaf-by-leaf inspection of 10 plants chosen at random in each plot, and counts recorded were of total numbers on individual onion plants. Yields were determined by counting the number of bushels of harvested onions in each plot. These were converted to bushels-per-acre values where plots were not of 1-acre size. Results are given in table 1. There was no evidence either from thrips counts or yields that the efficiency of DDT as a thrips poison was reduced by adding the fungicides used. There was no blight present in the area of the experiment, so no effect of the fungicides as to blight control was observed.

DDT AND SULPHUR.—Experimental work during the 1947 season was conducted on a somewhat different basis from that previously employed. Applications of insecticides were delayed until thrips populations had built up to an average of 6 to 8 per plant, at which time they were made in pairs about a week apart. Where necessary they were continued until the onion crop was mature. All dust treatments were made at an approximate rate of 35 pounds per acre per application and, excepting those involving aircraft, were applied with a 4 or 6-row self-propelled

[1] Thanks are due Dr. L. B. Norton and his assistants of the Cornell Univ. Agr. Exp. Sta. for conducting all of the analyses reported in this paper.

[2] *Dithane* 5 per cent in one, and "*Basicop*," a seven per cent metallic copper in another.

Table 1.—Average number of thrips per plant, and yields in bushels per acre in plots treated with DDT-fungicide dusts.

TREATMENT	NUMBER APPLICATIONS	DATE LAST APPL.	DATE THRIPS COUNT	AVE. NO. THRIPS/PLANT	YIELDS BU./ACRE
Fungicide No. 1[1]-DDT	2	July 8	July 30	34	699
Fungicide No. 2[2]-DDT	3	27	30	39	718
Fungicide No. 3[3]-DDT	3	27	30	75	932
DDT (3%)	2	26	30	36	726
Check	–	—	30	136	669

[1] *Dithane* Rohm and Haas Co.
[2] *Basicop* Sherwin-Williams Co.
[3] A product of Tennessee Copper Co.

Table 2.—Thrips populations and yields in bushels per acre in plots dusted with DDT and DDT-Sulphur.

TREATMENTS	DATE LAST APPLICATION	DATE THRIPS COUNT	AVE. NO. THRIPS PER PLANT	YIELDS BU./ACRE
DDT-Pyrophyllite (5-90)[1]	Aug. 12	Aug. 20	20	425
DDT-Pyrophyllite (10-80)[1]	Aug. 12	Aug. 20	24	438
DDT-Sulphur-Pyrophyllite (5-25-65)[1]	Aug. 12	Aug. 20	30	411
DDT-Sulphur-Pyrophyllite (5-50-40)[1]	Aug. 12	Aug. 20	29	413
Check (Untreated)	None	Aug. 20	114	360
Difference for significance at odds of 19:1			25	50
Difference for significance at odds of 99:1			34	—

[1]Dust formulation does not total 100 because source of DDT was a 50% wettable powder.

duster. DDT dusts other than those containing 5 per cent of the toxicant were mixed by the investigator in an agitator-type mixer, and all dusts contained pyrophyllite as the diluent.

An experiment to determine the effect of increasing the amount of DDT, and of adding sulphur to DDT dusts, was conducted on plots 6 rows wide by 350 feet long. Six replicates of four dust formulations and six appropriate checks were employed. One pair of applications was made July 17 and 24–25, and another August 6 and 12. The final thrips populations counts were made August 20 and are summarized in table 2. Yields in bushel crates per plot were converted to bushel-per-acre values in the table. As seen in the table, increasing the amount of DDT to 10 per cent did not give results superior to those obtained with the 5 per cent dust, and no value was evident in the addition of 25 or 50 per cent sulphur to the 5 per cent DDT. All dust treatments, however, did give significant reductions in thrips populations and increases in yields when compared with the untreated check plots. This is noteworthy in that thrips populations as a whole were relatively low, and plots were not uniform as to stands and yields because of factors of the environment.

AEROSOL COMPARED WITH DUST.—In another experiment an aerosol containing 10 per cent DDT, 5 per cent cyclohexanone, 5 per cent oil,[1] 20 per cent acetone, 3 per cent *Pyrethrum*[2] and 57 per cent methyl chloride was directly compared with a dust containing 5 per cent DDT on replicated plots of .33 acre each. The aerosol was dispensed at a rate of 7.5 pounds per acre per application from a rig[3] mounted on bicycle wheels and covering seven rows. A canvas back-drop was used to reduce drift of the aerosol. Three applications were made July 24, 29, and August 4 on the three replicates of each treatment. Yields, in total numbers of topped bushel crates per plot, and thrips counts are given in table 3.

It was quite evident that the DDT-pyrethrum aerosol was not superior to the regular-grind 5 per cent DDT dust, as results, both as to thrips populations and yields, were quite comparable. Although yields of treated plots were not signifi-

[1] *APS 202.*
[2] *DW 20.*
[3] This rig, similar to one described by Anderson & Brooks (1947), was loaned to the investigators through the courtesy of Mr. John Van Geluwe of the Coop. G.L.F. Soil Bldg. Service.

Table 3.—Thrips populations and yields in bushels per acre in plots treated with 5% DDT, and a DDT-pyrethrum aerosol.

TREATMENT	DATE LAST APPLICATION	DATE THRIPS COUNT	AVERAGE NO. THRIPS/PLANT	YIELD BU./ACRE
Aerosol (10% DDT+3% *pyrethrum*)[2]	Aug. 4	Aug. 15	48	370
DDT-Pyroph. Dust (5–90)[1]	Aug. 4	Aug. 15	27	342
Check	—	Aug. 15	120	283
Difference for significance at odds of 19:1			44	not sig.
Difference for significance at odds of 99:1			73	

[1] Dust formulation does not total 100 because source of DDT was a 50% wettable powder.
[2] *DW-20.*

cantly different from those of the checks, it is felt by the investigators that failure to obtain significant differences was due principally to the great variations between plots. Thrips damage was visibly evident in the untreated check plots. The aerosol, while costly, gave a rather efficient control. Considering the preliminary nature of this experiment and the particular advantage of light-weight equipment on muckland, it is certainly deserving of further consideration. If the DDT content or the pyrethrum content can be reduced in future tests without a sacrifice in control this type of insecticide might well have a place in the insect control program on muck crops.

AIRCRAFT APPLICATIONS.—In a series of tests with DDT and BHC dusts, a fixed wing plane[4] and helicopter[5] were used to develop and compare dusting schedules for aircraft applications. Non-replicated plots of 1.5 to 2 acres of onions were used. Six applications of three dusts containing 3 per cent DDT, 5 per cent DDT and 1.2 per cent gamma isomer of benzene hexachloride were made with the helicopter. A similar number of applications of a 5 per cent DDT dust were made by the fixed-wing plane on the same schedule. Dusts were applied at an approximate rate of 35 pounds per acre per application at about weekly intervals from mid-July to August 20. Thrips counts in table 4 are averages of counts of 25 plants chosen at random in the last count preceding harvest. Yields are of harvested onions in bushel crates per plot converted to a bushel-per-acre basis.

In explanation of these results it might first be pointed out that during most of the growing season the thrips populations were low, but toward the end of the season they built up very rapidly to the extent that unprotected onions were rather severely injured in some localities. Quite marked reductions in numbers of thrips, and considerably increased yields were obtained in plots dusted in these aircraft tests. However, the increase in yields in the various plots were not in direct proportion to reductions obtained in thrips populations, so it cannot be said that all yield increases were due to the thrips control even though a considerable portion of them probably were. Although unreplicated plots were used, and no statistical analyses were made, the consistent trend of lowered thrips populations and increased yields in treated fields is strongly indicative of the value of the treatments.

Table 4.—Thrips populations and yields in bushels per acre in plots treated with DDT and benzene hexachloride dusts applied by fixed wing plane or helicopter.

TREATMENT	DATE OF LAST APPLICATION	DATE OF COUNTS	AVERAGE NO. THRIPS/PLANT	YIELD BU./ACRE
Check	—	Aug. 22	140	419
3% DDT (helicopter)	Aug. 20	Aug. 22	95	530
5% DDT (helicopter)	Aug. 20	Aug. 22	34	499
5% DDT (fixed-wing plane)	Aug. 20	Aug. 22	24	590
1.2% benzene hexachloride (helicopter)	Aug. 20	Aug. 22	18	530
Check		Aug. 22	281	458

[1] 1.2% gamma isomer of hexachlorocyclohexane. Courtesy of Niagara Sprayer and Chemical Division of Food Machinery Corporation.

There seemed to be little difference between efficiency of the fixed-wing aircraft and the helicopter. Although the plot treated with the fixed-wing plane considerably outyielded that treated by the helicopter when both were applying 5 per cent DDT dust, the thrips counts showed the two means of applying materials to be about equal in effectiveness. During the early part of the season the helicopter applications were rather spotty and irregular with respect to distribution of the dust, but these irregularities were corrected both by changes made in the equipment at the Bell Aircraft Corporation and by experience and skill gained by the pilot. With some adjustments in the dusting apparatus on the helicopter, the two types of aircraft should prove of equal effectiveness in applying dust to onions.

It was obvious toward the end of the

[4] (Stearman P 17.)
[5] (Bell Agricultural Model.)

season that the 5 per cent DDT dust was more effective in thrips control than was the 3 per cent material when both were applied by helicopter. Yield figures substantiated this observation despite the lack of replicated plots. It was also evident that the dust containing 1.2 per cent gamma isomer of benzene hexachloride gave at least as good results as the 3 and 5 per cent DDT dusts, but further data concerning the possibility of food flavoring with benzene hexachloride is essential before this material can be recommended for thrips control on onions.

SUMMARY.—A control program for onion thrips of muck-grown onions was developed in numerous field tests in which timing of schedules and inclusion of various concentrations and forms of DDT were compared. Details of these tests are not presented in this paper but, briefly stated, the best program for New York conditions is one in which a 5 per cent DDT dust is employed in paired applications at 35 pounds per acre per application, beginning when the thrips populations have reached an average of about 6 per plant. The pair of applications are separated by an interval of 5 to 6 days to allow for hatching of eggs, and redistribution of thrips which were protected by leaf sheaths at the time of the first application.

Analyses of residues of DDT on onion bulbs from crops which had received field applications of dusts or sprays in amounts in excess of 5 pounds of the toxicant per acre showed residues of only 0.2 p.p.m. or less, thus indicating that hardly any hazard is involved in the use of DDT for thrips control on bulb onions.

In an experiment in which copper-containing fungicides were added to DDT dusts, it was found that these materials did not change the efficiency of DDT as a thrips poison.

A test was conducted in which dusts containing 25 and 50 per cent sulphur plus 5 per cent DDT were compared with 5 per cent and 10 per cent DDT dusts. Neither the addition of sulphur nor the increasing of the DDT content to 10 per cent improved performance over that obtained with the regular 5 per cent dust.

Fixed-wing plane and helicopter were both found to be efficient in distribution of dusts for thrips control.

A dust containing 1.2 per cent gamma isomer of benzene hexachloride was as effective as one of 5 per cent DDT both as to thrips control and yields. DDT plus pyrethrum in an aerosol formulation was as good as a 5 per cent DDT dust and, while costly, might be quite useful on muck-grown crops, where weight is such a factor, if the DDT content or the pyrethrum content can be reduced without sacrificing insecticidal efficiency for the control of thrips.

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DDT Residues on Alfalfa[1]

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The widespread use of DDT, 1-trichloro-2,2-bis(p-chlorophenyl) ethane, as an insecticide has brought about the problems of residues on foliage and the toxicity of these residues to warm-blooded animals. Some research has already been done on these problems, and much more is now in progress.

The toxicity of DDT to warm-blooded animals is well established. It has a strong affinity for and apparently acts upon the cholesterol in the lipoid membranes of nerve cells, thereby impoverishing or upsetting the balance of these cells (Laeuger *et al.* 1945). As pointed out by Decker (1946) and others, it is poisonous when ingested, injected or absorbed in considerable quantities. Draize (1944) reported that the lethal dose (L.D. 50) of DDT dissolved in corn oil and given orally was 200 mg. per kg. of body weight for rats, 400 for guinea pigs, and 400 for mice. Dosages reported by Woodard (1944) were >400 mg. per kg. of body weight for rabbits and >300 for chickens (L.D. 50). By comparison, the lethal doses of several other toxicants to the rabbit were reported by Haag (1937) as follows: lead arsenate, 100 mg. per kg. of body weight; nicotine, 30; strychnine, 4.24. Orr & Mott (1945) concluded that DDT was not acutely toxic when administered orally in dry powders or water suspensions to cows, horses, and sheep.

Various aspects of DDT toxicity have been studied by a number of investigators. Woodard and his co-workers (1945) discovered that DDT was stored in the fat of dogs and that accumulation and toxicity were influenced by the physical state of the DDT given. Telford & Guthrie (1945) found that 0.1 per cent DDT in food was toxic to lactating rats and their young, indicating that toxicity was transmitted through the milk to the young. Also, they revealed that rats fed solely on goat milk from animals receiving 1 gm. of DDT per 8 or 9 pounds of body weight died within a short time and that a half-grown kitten fed this same dosage died in three days. Wilson and his co-workers (1946) have demonstrated that dairy cows and sheep exhibit no observable ill effects from being fed four to five months on pea-vine silage treated with 1 pound of DDT per ton of fresh vines when put in the silo and that suckling calves and lambs showed no ill effects, although 15 p.p.m. of DDT was found to be present in the milk of cows. They further demonstrated that rats fed milk containing 44 p.p.m. showed distinct toxic effects, but those fed milk with 15 p.p.m. showed no effect. Burns (1946) found that DDT was secreted in the milk of dairy cows fed on hay from fields treated with DDT, that there was a decrease in gain of weight of feeder steers with an increase of DDT in the feed, that in rats the amount of growth was inversely proportional to the amount of DDT in the diet, and that DDT from the milk of dairy cows was stored in the fat of suckling calves up to as high as 825 p.p.m. Telford & Guthrie (1946) found that goats when given daily doses of 0.25 to 0.28 gm. of DDT per kg. of body weight, declined in milk production, and showed tremors; chickens fed mash containing 0.1 per cent DDT died in three days with typical intoxication. They found that a horse receiving a single dose of 0.26 gm. of DDT per kg. of body weight showed no ill effects. According to Plummer (1946) cattle were the most susceptible of domestic animals to DDT and swine were comparatively resistant.

Rats, pigs, and goats have been able to survive long feeding periods with foods containing DDT in the amounts of 500 to 1000 p.p.m. or more, according to Decker (1946); furthermore cattle, sheep, swine, goats, and laboratory animals can, over long periods of time, ingest daily amounts in excess of that expected as residues on plants without showing ill effects.

Some information is available on the persistence of DDT on crops. Manalo and his co-workers (1946) found that the weather, manner of application, and handling of fruits and vegetables made it difficult to correlate the amount of DDT

[1] The data contained herein are from a thesis presented by the senior author to the graduate faculty of the Alabama Polytechnic Institute in partial fulfillment of the requirements for the M.S. degree in Entomology.
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residues with the number of applications. One week after two applications of 5 per cent dust to beans, during which time there had been two hard rains, they found from less than 3 p.p.m. on green bean pods to over 200 p.p.m. on the leaves. According to Decker (1946) indications are that residues on apples, when sprayed four to seven times with 8 ounces to 1 pound of DDT per 100 gallons of spray, are less than the tentative tolerance of 7 p.p.m. established by the Pure Food and Drug Administration (1945). Also according to Decker, trimmings from lettuce heads and onion bulbs heavily dusted two or three times with 3 per cent dust left residues in excess of the tolerance but edible portions showed less than 1 p.p.m., and silage made from corn ten days after the last of three applications of 5 per cent dust at 20 pounds per acre had only 4 p.p.m. of DDT. Wilson and his co-workers (1946) found that pea vines treated with 50 pounds per acre of 5 per cent DDT dust and collected immediately had 9 to 13 p.p.m. Silage with 454 grams of DDT per ton in June had only 98.3 gm. per ton about six months later. They showed that no DDT was found in shelled peas from treated fields. Manalo and his helpers (1946) detected no DDT on the flesh of polished apples from DDT-sprayed trees and only a trace on unpolished apples. Arant (1948) found as much as 31 p.p.m. of DDT on peanut hay one day after dusting with 20 pounds per acre of 3 per cent dust and 20 p.p.m. 13 days after dusting. He found as little as 2 p.p.m. on peanut hay after a 5-week interval during which 5.9 inches of rain fell.

Since there is only a limited amount of information on DDT residues on forage crops, it appeared to be of value to investigate residues on alfalfa to which DDT dusts had been applied on varying rates and under wet and dry conditions. Experiments were conducted at the Agricultural Experiment Station of the Alabama Polytechnic Institute in the fall of 1946 to obtain information on DDT residues on alfalfa.

METHODS AND PROCEDURE.—Three per cent DDT dust in pyrophyllite was used throughout the experiment which was conducted on a second-year stand of alfalfa. Yield records at the end of the experiment revealed 1655 pounds of dry-weight alfalfa per acre. Dusts were applied under a paper-covered frame to plots 10 feet square. Treatments were not replicated. Before each application of dust was made, one-half of each plot was wet thoroughly with water from a knapsack sprayer. A weighed quantity of dust was then blown into the frame and allowed to settle 5 minutes. The plot treatments consisted of one, two and three applications at 10-day intervals at the rates of 15 and 30 pounds per acre. Samples of foliage were clipped with a pair of scissors from the wet and dry halves of each plot immediately after dusting and at 10-day intervals thereafter for 40 days. The samples were placed in bags and dried to constant weight in an oven at 40° C.

The xanthydrol-pyridine colorimetric method of Stiff & Castillo (1945) was used for the DDT determinations.[2] A No. 7-089 Fisher Electrophotometer with green filter was used.

RESULTS AND DISCUSSION.—In general, the more DDT that was applied to alfalfa the greater were the residues remaining

Table 1.—DDT residues in p.p.m. on alfalfa hay following treatments of wet and dry foliage with three per cent dust at the rate of 30 pounds per acre.

Number of Dustings	Days After Final Dusting									
	0		10		20		30		40	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
3	162	142	70	70	40	36	36	32	32	22
2	147	88	70	60	65	36	60	33	50	45
1	132	122	60	75	50	50	41	36	32	40
Average	147	117	67	68	52	41	46	34	38	36

[2] The writers are indebted to Dr. G. A. Schrader, Associate Professor of Chemistry, Alabama Polytechnic Institute, for suggestions in making the DDT determinations.

Table 2.—DDT residues in p.p.m. on alfalfa hay following treatments of wet and dry foliages with three per cent dust at the rate of 15 pounds per acre.

	Days After Final Dusting									
	0		10		20		30		40	
Dustings	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
3	99	32	88	60	—	—	89	55	—	—
2	45	45	39	10	32	22	38	35	22	19
1	40	—	—	—	—	—	36	36	10	10
Average	61	38	63	35	32	22	54	52	16	14

on the foliage. Analyses of samples collected immediately after the third application of 3 per cent dust on wet foliage at the rate of 30 pounds per acre revealed 162 p.p.m. of DDT. Samples taken immediately after a single application at the same rate analyzed 132 p.p.m. (Table 1). Where the rate of application was 15 pounds per acre, only 40 p.p.m. were recovered immediately following a single treatment of wet foliage with 3 per cent dust (Table 2). Similar trends occurred on foliage dusted while dry. These data emphasize the desirability of applying the minimum amount of DDT required for adequate insect control, particularly where the crop is to be harvested soon after dusting.

Larger residues of DDT were recovered from foliage dusted while wet than from that treated while dry, but the rate of decrease was greater on the wet foliage. Hay harvested immediately after dusting at the rate of 30 pounds per acre averaged 147 p.p.m. where the foliage was wet and 117 on foliage treated while dry (Table 1). After 40 days of weathering, the residues on harvested foliage decreased to 38 and 36 p.p.m. respectively. Similar results were noted on alfalfa dusted at the rate of 15 pounds per acre (Table 2).

A higher percentage of the DDT applied was recovered as residue after one application than after two or three. Immediately after one application at the rate of 30 pounds per acre to wet foliage, 24.3 per cent of the DDT was recovered. Only 13.5 per cent was recovered after two applications and 9.9 after three applications at this same rate (Table 3). This same condition was true after 40 days of weathering, but the differences were not as large.

The DDT residues decreased over the 40-day period of the experiment and tended to become equal on all plots receiving DDT at the same rate of application regardless of the number of applications at that rate. However, the greatest decrease of the DDT deposit occurred during the first 10 days after application. The average of 147 p.p.m. found immediately after application of 3 per cent dust at the rate of 30 pounds per acre to wet foliage dropped to 67 p.p.m. in 10 days. The corresponding drop on foliage treated

Table 3.—Percentages of DDT recovered from alfalfa hay after treatment of wet and dry foliages with three per cent DDT dust.

		Days After Final Dusting														
		0			10			20			30			40		
Treatment		Per Cent Recovered		Accum. Rainfall[1]	Per Cent Recovered		Accum. Rainfall	Per Cent Recovered		Accum. Rainfall	Per Cent Recovered		Accum. Rainfall	Per Cent Recovered		Accum. Rainfall
No. Appli.	Lbs. Per A.	Wet	Dry		Wet	Dry		Wet	Dry		Wet	Dry		Wet	Dry	
3	30	9.92	8.70	1.02	4.28	4.28	2.05	2.45	2.21	3.71	2.21	1.96	4.75	1.96	1.34	5.09
2	30	13.51	8.09	0.02	6.43	5.51	1.02	5.97	3.31	2.05	5.51	3.03	3.71	4.59	4.13	4.75
1	30	24.26	22.43	0.00	11.03	13.79	0.02	9.19	9.19	1.02	7.54	6.62	2.05	5.88	7.35	3.71
Ave.	30	15.90	13.07	0.35	7.25	7.86	1.03	5.87	4.90	2.26	5.09	3.87	3.50	4.14	4.27	4.52
3	15	12.12	3.92	1.02	10.78	7.35	2.05	—	—	3.71	10.91	6.74	4.75	—	—	5.09
2	15	8.27	8.27	0.02	7.17	1.83	1.02	5.88	4.04	2.05	6.99	6.43	3.71	4.04	3.49	4.75
1	15	14.71	—	0.00	—	—	0.02	—	—	1.02	13.24	13.24	2.05	3.67	3.67	3.71
Ave.	15	11.70	6.09	0.35	5.98	3.06	1.03	5.88	4.04	2.26	10.38	8.80	3.50	3.85	3.58	4.52
Grand Ave.	xx	13.80	10.28	0.35	7.94	6.57	1.03	5.87	4.69	2.26	7.73	6.34	3.50	5.03	3.99	4.52

[1] Rainfall subsequent to first and previous to last application of dust.

while dry was from 117 to 68 p.p.m. The major part of this high initial drop was probably a result of shattering, rainfall, or other mechanical processes while the slower more gradual subsequent reduction during the next 30 days was probably a result of decomposition. Some variations occurred between individual plots, but the trend to equalization of residues after 40 days is apparent from the data. These data indicate that 40 days approached the time limit for persistence of DDT exposed to general weathering under the conditions of the experiment.

Further research is needed not only on the persistence of residues for longer than 40 days but also on the effect of temperature and rainfall as well. The experiment reported here was conducted during the fall when the maximum and mean temperatures were considerably below those occurring during the summer months. All plots received about the same amount of rainfall, and it was impossible to determine any direct effect of rainfall on residues.

DDT was present in significant amounts on all foliage 40 days after dusting, regardless of treatment. The lowest residue of 10 p.p.m. occurred on alfalfa dusted once with 3 per cent dust at the rate of 15 pounds per acre. Where the rate of application was 30 pounds per acre, 30 to 40 p.p.m. remained after 40 days. As far as the visible effect on the health of animals is concerned, these amounts of DDT could be fed safely to dairy cattle for several months as evidenced by the work of Burns (1946). Calvery (1945) found that monkeys are apparently unaffected by 50 mg. per kg. of body weight per day for 16 months; however, histologic examinations of the tissues of rats fed 100 p.p.m. periodically for 2 years indicated that there was damage to liver tissue. The ultimate effect of feeding foliage containing DDT residues to farm animals over a period of years is as yet undetermined.

It has been established that DDT on feed passes from dairy cows in the milk; the continued feeding of foliage bearing DDT residues to dairy cows may result in the passing of this chemical on to human consumers. Burns (1946) found as high as 825 p.p.m. of DDT in the leaf fat of a calf suckling a cow fed 184 p.p.m. of DDT on hay for 143 days. Also significant is the fact that meat from beef animals fed on feeds containing DDT may pass the chemical on to the consumer.

SUMMARY.—One, two, and three treatments of alfalfa with 3 per cent DDT dusts were made at 10-day intervals on wet and dry foliage at the rates of 15 and 30 pounds per acre. Samples of foliage were collected immediately after the last application and at 10-day intervals thereafter for 40 days. The DDT residues were determined on oven-dried samples by the Stiff and Castillo xanthydrolpyridine colorimetric method. The maximum amount found was 162 p.p.m. on hay harvested immediately after the third dusting at the rate of 30 pounds per acre. The minimum amount of 10 p.p.m. was on foliage collected 40 days after receiving a single application of dust at the rate of 15 pounds per acre. The amount of residue increased with the number of dustings, then decreased over a 40-day period following the final treatment and tended to become equal on all plots dusted at the same rate, regardless of the number of applications at that rate. More residue persisted on foliage dusted while wet than on that treated while dry, but again there was a tendency toward equalization after 40 days of weathering. The effect of feeding DDT residues to animals over a period of years has not been determined.

12–27–47.

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New Insecticides for Corn Earworm Control[1]

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Mineral oil for the control of the corn earworm, *Heliothis armigera* (Hbn.), has been tried for several years. Barber (1942) states that mineral oil was used for this purpose as early as 1936. Investigations in 1939 showed that the oil treatment was more effective when pyrethrins or dichloroethyl ether was added. Carruth (1940) reported on the use of mineral oil for corn earworm control, stating that 0.5 to 0.75 cc. of 200 viscosity oil was a sufficient dose for one ear. Pepper (1941) found that when used alone white mineral oils of high viscosity were more effective than those of low viscosity. Oils ranging from 100 to 150 viscosity with an insecticide added were effective and less expensive than higher viscosity oils.

The use of an oil, with or without an insecticide added to it, presents certain difficulties or disadvantages in the treatment of corn. Application as most investigators have found, must be timed so as not to interfere with pollination of the kernels. This means that the silks must be partially wilted before an oil can be applied to the tip of the ear. Unfortunately, this delay in protecting the ear may provide time enough for the larva to enter the silks and damage the ear.

Certain insecticides when used with an oil affect the taste and odor of the corn. Corn treated with some materials, such as dichloroethyl ether, may have an undesirable odor and taste. Another condition that might be objectionable to consumers is the oily appearance and feel of ears treated with mineral oil.

B. B. Fulton and R. W. McMillen, investigating improved methods of corn earworm control, found that the addition of DDT to the oil greatly increased the efficiency of control (Anon. 1945). Subsequent investigations by Fulton (1946) showed that DDT sprays made from wettable powder or water miscible emulsion concentrate gave control almost equal to that obtained from using DDT in oil. DDT sprayed on the silks with a disc nozzle did not give as good control as when applied with a jet-like nozzle, delivering a solid stream.

PURPOSE OF THE 1947 EXPERIMENTS.—Corn earworm experiments were continued in the summer of 1947 to test new insecticides in spray and dust forms. DDT in mineral oil was again used. It served as a basis for comparing the effectiveness of the other materials used. Two sweet corn hybrids, MC78 and C81×C88,[2] were

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[2] MC78 (a top cross hybrid, Wappoo×M133) was developed

grown and their performance observed.

MATERIALS USED.—Three types of insecticidal applications were used in this experiment, (1) oiling, (2) spraying, and (3) dusting. Only one treatment had oil, and this was a 0.25 per cent of DDT in a white mineral oil of 310 Saybolt viscosity. Dust treatments were made with a five per cent concentration of the following materials: chlordan, chlorinated camphene, DDT, benzene hexachloride, and bis(methoxyphenyl) trichloroethane, an analog of DDT. Two dusts of *Ryania*[3] were used at the concentrations supplied by the manufacturer.

Four different sprays were used at a concentration of 0.25 per cent. These sprays were diluted from concentrated forms of *Ryania*,[4] DDT water miscible emulsion, parathion, and dichloro-diphenyldichloroethane[5] which is reported to be less toxic to warm-blooded animals than DDT. A complete listing of these materials and the source of supply are given in table 1.

PROCEDURE.—The one application made with the DDT-oil treatment was timed so that the ears were treated when the silks began to dry. Since all the ears were not ready for treatment on the same day the material was applied at three day intervals. However, each ear received only one application. Oil was applied directly to the tip of the ear in the silk channel with a hand oiler. Each ear received about one cc. of 0.25 per cent DDT in oil.

The dusts were applied directly to the silks at two day intervals with a plunger-type hand duster. Five dust applications were made beginning when the silks were two to three inches long. It was estimated that the dusts were applied at the rate of 10 to 15 pounds per acre.

Sprays were applied at 3-day intervals. Four applications were made, except in the parathion treatment where only three applications were made. Spray materials were applied directly to the tip of the corn husk by delivering a solid stream of liquid into the center of the silk channel. Each ear received about five cc. of the spray material with each one of the several applications.

Treatments were made on unreplicated plots of 50 lineal feet of row of each of the two corn hybrids. Rows were spaced 3.5 feet apart. There were approximately 50 hills of corn in each plot. The distribution of the hybrids and of the treatments was randomized in the experimental field. The same treatments were used with each hybrid except that MC78 received a treatment with parathion and dichlorodiphenyl-dichloroethane whereas C81×C88 did not.

Harvest of mature ears began 8 days after the first treatment and was continued for 7 days thereafter. Counts were made of the number of clean marketable ears as well as the damaged ears in each row of the experimental plot. The results are presented in table 1. In addition to this infestation record, observations were made on the quality and taste of the treated corn.

RESULTS OF INSECTICIDAL TREATMENTS.—The highest percentage of worm-free ears in either hybrid was obtained with the 0.25 per cent DDT-oil treatment. In MC78, dichlorodiphenyl-dichloroethane was next best to the oil treatment followed by water miscible DDT and *Ryania*. In C81×C88, 5 per cent DDT dust and 0.25 per cent water miscible DDT spray produced the highest percentage of worm-

Table 1.—Results of insecticidal treatments for the control of the corn earworm attacking two sweet corn hybrids, MC78 and C81×C88.

METHOD OF APPLICATION	INSECTICIDES	PER CENT CLEAN EARS	
		Hybrid MC78	*Hybrid C81×C88*
Oil	DDT, 0.25% in mineral oil	82.5	75.5
Spray	Dichlorodiphenyl-dichloroethane[1] 0.25%	77.2	—
Spray	DDT, water miscible, 0.25%	69.2	59.3
Spray	*Ryania*,[2] 0.25%	61.3	51.2
Dust	*Ryania* (equivalent to 40% wood)	54.8	43.2
Dust	γ-Benzene hexachloride,[3] 5%	46.4	51.9
Dust	*Ryania* (40% wood)	38.1	33.9
Spray	Parathion[4] 0.25%	37.1	—
Dust	DDT, 5%	35.7	61.2
Dust	Bis(methoxyphenyl) trichloroethane,[5] 5%	29.3	31.8
None	Untreated Check	22.3	27.0
Dust	Chlordan, 5%[6]	12.4	40.4
Dust	Chlorinated camphene, 5%[7]	11.2	28.6

[1] Manufactured by Rohm and Haas Co., Philadelphia, Penn.
[2] *Ryania* compounds supplied by Merck and Co., Rahway, New Jersey.
[3] Supplied by California Spray-Chemical Co., Elizabeth, N. J.
[4] Supplied by American Cyanamid Corp., New York, N. Y.
[5] Manufactured by E. I. du Pon de Nemours and Co., Wilmington, Delaware
[6] Supplied by Riverdale Chemical Corp., Harvey, Ill.
[7] Supplied by Hercules Powder Co., Wilmington, Delaware.

by the U. S. Regional Breeding Laboratory, Charleston, South Carolina. C81×C88, produced by the Connecticut Agricultural Experiment Station, New Haven, is briefly described as a yellow seeded *Redgreen*.

[3] *Ryania 40-D* (40 per cent ground wood) and *Ryania* ED-41 (made from *Ryania* extract and with insecticidal activity equivalent to *Ryania 40-D*.

[4] *Ryania* SC-50.

[5] Rothane WP-50

free ears next after the DDT in oil treatment. The 5 per cent DDT dust treatment in MC78 had 35.7 per cent clean ears as contrasted with 61.2 per cent in C81×C88. The lowest percentages of worm-free ears were recorded for bis (methoxyphenyl)trichloroethane, for the untreated check, for chlordan and chlorinated camphene in MC78 and for *Ryania*, bis (methoxphenyl) trichloroethane, chlorinated camphene, and the untreated check in C81×C88.

In order to obtain information on the taste and quality of treated corn, a number of ears that had undergone the same treatment were distributed for taste tests to two or more people. The only treatments that could be said to have flavored the quality of the ears were 0.25 per cent DDT in oil and five per cent benzene hexachloride dust. One out of 70 ears treated with dichlorodiphenyl-dichloroethane (0.25 per cent liquid) was reported as off-taste. Corn treated with other insecticides was reported to be of good quality and evidently had no seriously objectionable taste or odor.

SUMMARY.—The results of tests for the control of the corn earworm attacking two sweet corn hybrids, MC78 and C81×C88, are reported. Treatments were made with (1) a hand oiler, (2) a small garden-type sprayer with a jet-type nozzle, and (3) a plunger-type hand duster.

DDT, 0.25 per cent in mineral oil, resulted in the best control of the corn earworm but it flavored the corn. Five per cent benzene hexachloride dust also flavored the corn. Water miscible DDT, 0.25 per cent, dichloro-diphenyl-dichloroethane, 0.25 per cent, *Ryania* 0.25 per cent spray, and *Ryania* dust and 5 per cent benzene hexachloride dust resulted in good but not complete control of corn earworms. Corn treated with chlordan, chlorinated camphene, and bis (methoxyphenyl) trichloroethane, 5 per cent dusts, had the lowest percentage of worm-free ears.—2-5-49.

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Comparative Compatibility and Residual Toxicity of Organic Insecticides as Based on Grasshopper Control

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Griffiths *et al.* (1947) reported satisfactory control of the American or bird grasshopper, *Schistocerca americana*, with four different materials; chlordan, chlorinated camphene, benzene hexachloride, and parathion. These were used in citrus groves in Florida and were tested either by themselves or in combination with wettable or dusting sulfur. Some or all of them have also shown some promise (Thompson & Griffiths 1947) for use on other citrus pests such as aphids, plant bugs, and scales. The following paper deals with the comparative residual toxicity and the compatibility with standard citrus sprays of these materials.

During field trials in the summer of 1947 the four insecticides were used at the following dosages: 1.5 lbs. of technical chlordan per acre; 4.5 lbs. of chlorinated camphene per acre; 0.45 lb. of gamma isomer of benzene hexachloride per acre; and 0.45 lb. of parathion per acre. As

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previously reported (Griffiths *et al.* 1947) these materials gave satisfactory control at these comparative dosages. These recommendations were higher than similar recommendations from other sections of the United States (Hill & Hixsom 1947; Hinman & Cowan, 1947; List & Hoerner, 1947; Weinman *et al.*, 1947). This was primarily due to the fact that grove land offers a very extensive leaf surface which must be covered if satisfactory control is to be obtained. The American grasshopper is a large individual and its size undoubtedly contributes to the problem of control.

Reference to the authors listed above indicates, in general, that chlordan and chlorinated camphene have shown longer residual toxicity than benzene hexachloride when used on grasshoppers in the middle-west and west. Weinman *et al.* (1943) also noted the need for increased dosages where adult hoppers were involved or where the type of crop was dense or old and tough. During field trials in July and August 1947 some observations pertinent to residual toxicity of these compounds were made in Florida grove land. On plots where grasshopper adults were caught and caged at varying intervals after treatment, it was found that both the gamma isomer of benzene hexachloride and parathion showed little or no residual toxicity after 3 days of weathering. On the other hand, both chlordan and chlorinated camphene were still killing grasshoppers for at least a week after treatment. The insecticides were applied both as dusts and as sprays. July and August are characterized by almost daily showers in central Florida and, under these circumstances, the dusts appeared to be as satisfactory as sprays as long as both were applied at the same amount of toxicant per acre. It appeared that none of these materials could be depended upon to prevent infiltrations from adjacent fields for more than a week under Florida conditions. With these observations as a background a series of cage tests was planned in order better to determine relative residual toxicities as well as toxicities when combined with standard citrus spray materials.

A young grove with trees less than 48 inches high was selected as a site for the proposed tests. Cages measuring 36″ by 36″ by 42″ were used to enclose the trees. The first two tests were used to study the residual toxicity of different formulations of these compounds. Treatments were in duplicate and for each tree and its surrounding check or square five gallons of spray were used. Thus, both the tree and the adjacent cover crop was sprayed. Each square represented approximately 0.017 acre. Therefore, 0.017 of the acre dosage[2] was added to five gallons of water and the entire amount sprayed onto the tree and the adjacent cover crop. Where dusts were used, the same amount of active ingredient was applied. Following the application, the trees were caged and 10 adult grasshoppers were introduced into the cage. Grasshoppers were reintroduced at varying intervals and mortalities were recorded daily. No data are presented here, but in all instances the data substantiated the observations which had been made during the earlier field trials. Thus, chlorinated camphene and chlordan exhibited significant residual toxicity for more than a week whereas benzene hexachloride and parathion showed little or no residual toxicity afrer 3 days. There were daily showers during the course of the first test. During the second trial, however, practically no rain fell. Dusts were as satisfactory as sprays under wet conditions but, under dry conditions, the sprayed materials appeared to give more prolonged toxicity. Not only was this true but, when there was no rain, wettable materials were generally inferior to emulsifiable materials or wettable powders in oil emulsions under the dry conditions. This fact cannot be adequately explained here, but it is believed that wetting and sticking agents used were probably responsible. On the basis of these data it was concluded that the type of formulation to be used would be dictated by the cost and availability of the materials.

In October a series of 10 different tests was started to determine the compatibility of these four insecticides with wettable sulfur, 40 per cent dinitro-o-cyclohexylphenol, neutral copper, and a zinc sulfatelime mixture. These were continued into December until such a time as the lack of grasshopper activity made further tests impracticable. Five gallons of spray were again used per 0.017 acre and the same amount of insecticide used as in the pre-

[2] Chlordan 1.5 lbs., 4.5 lbs. chlorinated camphene, 0.45 lb. gamma isomer of benzene hexachloride and 0.45 lb. parathion.

Table 1.—Per cent mortalities of grasshoppers isolated on citrus trees sprayed with four insecticides in combination with standard spray materials 24 hours after treatment.

Materials Combined with Insecticides	Toxicant in 100 Gals.	Insecticide			
		Chlordan	Chlorinated Camphene[1]	Benzene Hexachloride[2]	Parathion
		Toxicant per acre			
		1.5 lbs.	4.5 lbs.	0.45 lb.	0.45 lb.
		Date of Application			
		Dec. 8	—	Dec. 1	Nov. 24
None	0	29	50	56	80
Wettable sulfur	10 lbs.	43	43	73	70
Dinitro-o-cyclohexylphenol (40%)	0.67 lbs.	78	30	55	60
$ZnSO_4$+Lime	3+1 lbs.	25	35	90	64
Neutral Copper	3 lbs.	30	37	67	80

[1] Average figures from several tests.
[2] Gamma isomer.

vious test. The other spray ingredients were used at the standard rate per 100 gallons of spray. These rates are given in table I. The first four tests were concerned with combinations of sulfur, zinc sulfate, and dinitro-o-cyclohexylphenol with the four insecticides and the next two were with neutral copper. The last four trials tested each insecticide with the other four materials on the same date. Table 1 presents the results from these last four tests for chlordan, parathion and benzene hexachloride. The data for chlorinated camphene is a composite of the earlier tests. This was necessitated by the fact that cold and cloudy weather in December invalidated the final test with this insecticide. The mortality figures shown are for grasshoppers which were isolated on the tree 24 hours after spraying. The intervals of time to final mortality varied. This was due to the fact that on either cool or cloudy days, the grasshoppers hung on the sides of the cage and neither fed nor moved around. During periods like this there was no mortality with any of the treatments.

Untreated controls were always included and they averaged less than 5 per cent mortality. Thus, all combinations shown in table 1 exhibited significant mortalities. Results are variable and the only possible conclusion is that none of the combinations tried had any marked effect in reducing the toxicity of the insecticide. Much of the variation is undoubtedly caused by the fact that different types of wetting and sticking agents were present in each of the mixtures. All materials were commercial products and the factor of wetting agents was beyond the control of the investigators. In general the low mortality figures would be attributable to decreased activity of the insects in November and December. The results would indicate that these four insecticides may be used in combination with most of the standard citrus spray mixtures.

SUMMARY AND CONCLUSIONS.—A series of observations and cage tests on the residual toxicity of chlordan, chlorinated camphene, benzene hexachloride, and parathion are described. In addition these insecticides were tested for their compatability with wettable sulfur, dinitro-o-cyclohexylphenol, neutral copper and zinc sulfate-lime mixtures.

Under Florida citrus grove conditions benzene hexachloride (0.45 lb. gamma isomer per acre) and parathion (0.45 lb. active ingredient per acre) were found to exhibit little if any residual toxicity after three days. Chlordan (1.5 lbs. per acre) and chlorinated camphene (4.5 lbs. per acre) has some toxicity for more than one week. Dusts or sprays appeared to be about equally satisfactory. All four materials were found to be compatible with wettable sulfur (10 lbs. per 100 gallons), 0.67 lb. 40 per cent dinitro-o-cyclohexylphenol per 100 gallons), neutral copper (3 lbs. 34 per cent metallic copper per 100

gallons) and zinc sulfate (3 lbs. zinc sulfate plus 1 lb. lime per 100 gallons). All such combinations gave comparable mortalities.—3-31-48.

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Corn Rootworm Control Tests with Benzene Hexachloride DDT, Nitrogen Fertilizers and Crop Rotations[1]

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Some insects are readily controlled by good crop practices. This is true of the northern corn rootworm, *Diabrotica longicornis* (Say),[2] the western corn rootworm, *D. virgifera* Lec., and the southern corn rootworm, *D. undecimpunctata howardi* Barber. The northern and western species are effectively controlled by crop rotation, whereas the injury caused by the southern species may be reduced by timely planting, clean cultivation, destroying weedy field margins and the alternate use of legumes. These control practices have been recommended by entomologists for many years and have generally proven to be efficient.

In recent years these insects have increased to extremely large populations in Nebraska due to a series of years in which temperature and rainfall have been favorable for rootworm development. Populations have been intensified by the continuous growth of corn on the same land. Farmers growing corn in irrigated areas have experienced the greatest losses. The experiments outlined and discussed in this paper represent an attempt to develop a supplementary control measure for the farmers of the state. All three species of rootworms were present in the different experimental fields, but the western corn rootworm was the most abundant. The northern and southern species comprised approximately 10 per cent of the populations except in a fertilizer experiment located at Wood River, Nebraska, where about 25 per cent were the northern species.

ROTATIONS AND FERTILIZERS.—Crop rotation as a control for the northern corn rootworm seems to have been discovered by entomologists and used by farmers long before experimental evidence was collected. Riley (1880) first recorded the species as injuring corn. Forbes (1894) wrote of rotations as a simple, complete, established means of preventing injury, by which at least two and possibly three years of control could be obtained. Sorghum and broom were not considered by him to be good alternate crops. He also cited the maintenance of good soil fertility with the use of manures and fertilizers as the only other preventive measure, stating that these measures did not control the insect but permitted the corn to produce a crop under light infestations. Forbes did state, however, that he had speculative evidence that certain fertilizers such as potash salts might have some deleterious effect on larvae in the soil. Chittenden (1905), quoting Forbes, stated that although rotations gave control of the corn rootworm, it was imprudent to plant corn in fields or meadows in which the beetle had been observed in abundance feeding on clover and certain

[1] Published with the approval of the Director as Paper No 446, Journal Series, Nebraska Agricultural Experiment Station.

[2] Recent correspondence with Mr. H. S. Barber of the United States National Museum indicates some confusion in the naming of the northern corn rootworm and the western corn rootworm. Until the synonymy of the group has been thoroughly studied the designation made here should serve to identify the species.

weeds in late October of the previous year. Webster (1912) made a check on the efficiency of crop rotation by field observation and examination and found it to be effective. He further concluded that failure to control could be caused by early corn maturity causing the adults to move to nearby clover fields for feeding and egg laying. Webster also stated that overflowing and flooding of rivers did not cause a high mortality of rootworm eggs. Bigger (1932), working with several agronomic rotation systems, failed to obtain control of the northern corn rootworm in a 3-year system where corn was grown two years, with an oats and sweet clover combination the alternate year. Control was obtained, however, in a 3-year system, using corn, oats and red clover and wheat and sweet clover. Using 4-year rotation systems, Bigger & Flint (1939), obtained no great average differences in the control of rootworms, except between first and second year corn, despite differences in cropping practices. They did find, however, that southern corn rootworms were much more abundant on first than on second-year corn at on station.

Gillette (1912) first recorded *Diabrotica virgifera* Lec., the western corn rootworm, as injuring the roots of corn. He stated that it produced one brood a year and had practically the same life history as *D. longicornis* (Say). From this he inferred that rotation would give control. Hoerner (1925), discussing the effectiveness of rotations for the control of this species, cited a reduction in total yield of corn silage of 47 tons between second and third-year corn on a 7.5 acre field in Colorado.

Procedure.—To determine the effects of fertilizer on rootworm injury, records of such damage were obtained from soil fertility tests being conducted by the University of Nebraska, Department of Agronomy at Wood River and Holdrege, Nebraska, in 1946. At Wood River, 12 different commercial fertilizer treatments were tested on an irrigated field that had been in corn several years. The fertility was low and the rootworm infestation high. All treatments were applied with hand-operated equipment and replicated five times in plots four rows wide and 50 feet long. The Holdrege experiment was conducted on an irrigated farm in a series of 0.2 acre plots established by the Department of Agronomy, where a comparison is being made of the benefits derived from various rotation and fertility practices. Rootworm damage was determined at both locations on the basis of the number of stalks lodged 30 degrees or more from the vertical position in early September.

Table 1.—Effect of method and time of application and kind of commercial fertilizer on lodging and yield of corn heavily infested with rootworms. Wood River, Neb., 1946.

Treatment N-P_2O_5-K_2O Lbs. per Acre	Method and Time of Application	Per Cent Stalks Lodged 30° or More on Sept. 10	Yield Bu. per Acre[1]
80-0-0	at last cultivation	34.5	93.5
5-10-5 and 40-0-0	at planting time at last cultivation	39.2	92.9
40-40-0 and 40-0-0	at planting time at last cultivation	40.1	103.6
0-40-0 and 40-0-0	at planting time at last cultivation	44.9	87.3
40-0-0	plowed under	48.7	76.5
40-40-40	at planting time	50.3	67.0
40-0-0	at last cultivation	59.2	85.4
40-0-0	at planting time	64.5	75.4
40-40-0	at planting time	72.7	63.7
5-10-5	at planting time	83.8	43.4
0-40-0	at planting time	88.3	43.1
None	—	81.7	40.8
Difference required for significance at 19:1 odds		15.8	6.1

[1] Calculated on the basis of 15.5 per cent moisture.

Results.—At Wood River a highly significant correlation was found between the percentage of stalks lodged and the yield. Table 1 summarizes these data. The lowest percentage of lodging caused by rootworms and the highest yields occurred in plots given an application of 40 to 80 pounds nitrogen fertilizer per acre at the time of the last cultivation. Lowest yields and the highest degree of rootworm injury, as evidenced by lodging, occurred in plots not treated with nitrogen. Some lodging in the nitrogen plots was due to rank growth. Corn growing in plots on which nitrogen was plowed under before planting, or applied at planting time, showed an intermediate amount of lodging and yields. Phosphorous had no effect and potash was not used comparatively. Nitrogen apparently did not affect the rootworm population but brought about quick recovery (Fig. 1).

Although rootworm populations were much lighter, similar results were obtained in the soil fertility and rotation experiment at Holdrege (Table 2). The greatest amount of lodging was recorded in plots planted to corn for three successive years. The addition of manure or nitrogen or both fertilizers increased the yield and reduced the amount of rootworm damage as evidenced by lodging.

SOIL INSECTICIDE TREATMENTS.—DDT

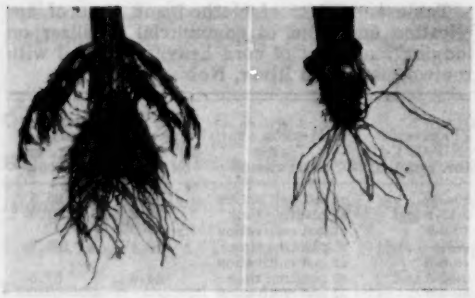

FIG. 1.—Root recovery (left) following application of nitrogen as a nitrate at the time of last cultivation. Right, check plant. Photographed August 8, 1947.

and benzene hexachloride are being widely tested as soil insecticides. Benzene hexachloride has been especially promising in this respect. Mitchell (1946), studying soil pests of tobacco, tried a 5 per cent mixture of γ-benzene hexachloride and china clay plus a fertilizer. This mixture, which was applied at rates of 150 to 200 pounds per acre at the time the ground was being prepared for planting, significantly reduced white grub populations. In New South Wales, Wallace (1946) experimented successfully with soil treatments of DDT and benzene hexachloride to combat adults of the black beetle. *Heteronychus sanctae-helenae*, Blanch. In England, Thomas & Jameson (1946) obtained a 65 per cent reduction of wireworms following a broadcast application of 300 pounds of a dust containing about 0.25 per cent gamma isomer (or 0.84 pounds) per acre. When the material was drilled in at one-third this rate a 50 per-cent reduction was recorded. A more detailed account by Jameson *et al.* (1947) showed that yields of oats and winter wheat were increased from two to five times by controlling wireworms with benzene hexachloride (13 per cent gamma isomer) broadcast at 6 pounds per acre and combine-drilled at 2 pounds per acre. Roberts (1947), working in Texas with false wireworms of the genus *Blapstinus*, mixed 4 grams each of benzene hexachloride (0.575 per cent gamma) and DDT (25 per cent) in soil around small cantaloupe plants. Both materials protected the plants and observations indicated that 84 per cent of the wireworms were killed with benzene hexachloride and 68 per cent with DDT. In New Jersey, Pepper *et al.* (1946, 1947) obtained 98 per cent wireworm control with 2 pounds gamma benzene hexachloride per acre broadcast on the surface in the spring and harrowed into the top soil just prior to potato planting. When 1.6 pounds gamma benzene hexachloride were broadcast and disked into the soil in the fall a 99 per cent kill of wireworms resulted. Practical control of wireworms in Connecticut was obtained with even smaller amounts of benzene hexachloride by Greenwood (1947). His data showed that 0.2 to 0.25 pounds of γ-benzene hexachloride per acre was effective when the material was applied broadcast with a grain drill and worked into the soil with a disk-harrow. In North Dakota, Post *et al.* (1947) secured almost 90 per cent control of wireworms with a benzene hexachloride dust containing 1 per cent of the gamma

Table 2.—Effect of various rotations and fertilizer treatments on lodging and yield of corn infested with rootworms. Holdrege, Neb., 1946.

Rotation and Treatment			Per Cent Stalks Lodged 30° or More Sept. 11, 1946	Yield Bu. per Acre in 1946[1]
1944	1945	1946		
Sweet Clover	Corn	Corn (40 lbs. N.)[2]	1.5	102.6
Sweet Clover	Corn	Corn	4.0	89.4
Corn (40 lbs. N.)	Corn (M-10T)[3]	Corn (M-10T and 40 lbs. N.)	5.0	100.5
Corn (40 lbs. N.)	Corn (M-10T)	Corn (M-10T)	9.0	83.2
Corn & Sweet Clover	Corn (40 lbs. N.)	Corn (40 lbs. N.)	4.2	96.2
Corn & Sweet Clover	Corn (80 lbs. N.)	Corn (80 lbs. N.)	10.0	97.9
Corn (80 lbs. N.)	Corn (M-10T)	Corn (40 lbs. N.)	6.0	90.1
Corn (80 lbs. N.)	Corn (M-10T)	Corn	20.5	70.1
Sweet Clover	Sweet Clover	Corn (40 lbs. N.)	19.0	117.4
Sweet Clover	Sweet Clover	Corn	8.8	111.8
Corn	Corn	Corn	31.8	45.7

[1] Calculated on the basis of 15.5 per cent moisture.
[2] Nitrogen fertilizers (Ammonium nitrate) applied at the time of last cultivation.
[3] Manure (10 tons per acre) applications made in the spring.

isomer applied with a wheelbarrow-type duster at the rate of 20 pounds per acre. Plots were disked or harrowed to a depth of 5 inches a few hours following the applications.

Fulton (1946) found that DDT and benzene hexachloride gave promise as a practical means of protecting young corn plants from the southern corn rootworm. Grayson & Poos (1947) likewise obtained promising results with these two chemicals as soil treatments for controlling the same species.

The effects of benzene hexachloride on soil organisms or soil structure are unknown. When Wilson & Choudhri (1946) mixed DDT with soil at rates in excess of those that would ever be used entomologically, the material was not injurious to microorganisms. Furthermore, ammonification, nitrate accumulation and normal concentration of the soil salts "did not seem to be seriously modified." Appleman & Sears (1946) found that nodulation of legumes grown in sand was not affected unless the amount of DDT (10 per cent) reached a concentration of 1000 pounds per acre. There was, however, some inhibitory effect on the height of the plants at concentrations of 100 pounds or 10 pounds of actual DDT per acre. Plants grown in soil "did not develop symptoms of injury to the same degree as those grown in sand." These differences may, as these investigators state, "have been due to adsorption of DDT by the soil colloids. In no case were unfavorable results obtained in soil when the treatment with DDT did not exceed 100 pounds per acre." According to Smart (1947) oats sown in England through a combine drill with fertilizer and benzene hexachloride were stronger, darker green and broader-leaved than the control plants. The author assumed that liberated chlorine affected a partial sterilization of the soil and as a result increased the amount of available nitrogen.

Procedure.—Two experiments involving soil applications of benzene hexachloride and DDT were conducted near Lexington, Nebraska in Dawson County, on soil classified as Hall silt loam.[1] In one experiment, hereafter designated as a pre-plowing test, the materials were sprayed on the surface of the ground one day ahead of plowing and about a week before

[1] The cooperation of the farmer, Harold Fagot, is gratefully acknowledged.

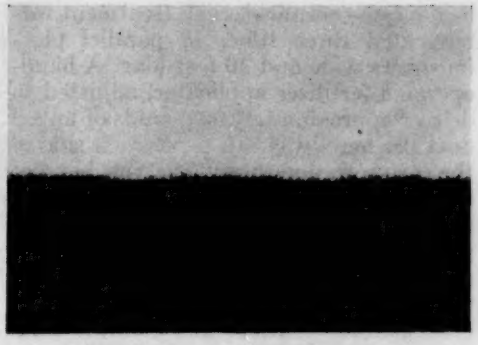

FIG. 2.—Differences in stalk growth following insecticidal kill of rootworms. Reading from left to right peaks of plant growth were obtained with 2 pounds gamma benzene hexachloride, one-half pound of gamma benzene hexachloride and 10 pounds of DDT to the acre. Note depressed areas over 10-foot untreated alleys. Photographed August 8, 1947.

the corn was planted. In the other, a side-dressing test, applications were made with a soil fertilizer applicator just prior to the first cultivation. The irrigated field, in which both tests were located, had been in corn for the previous three years. Last season's stalks were cut with a stalk-cutter and the field double-disked twice before it was plowed to a depth of 7 or 8 inches. The corn was surface planted.

Each treatment in the pre-plowing experiment was replicated three times in parallel plots 30 feet wide which extended across the rows for 200 feet. Applications were made on May 1 with a truck-mounted power sprayer, operating at 190 pounds pressure. A 10-foot boom of the weed sprayer type, equipped with 0.06 nozzle openings, was operated about 1 foot above the surface of the soil. From this height the spray was delivered uniformly and with a minimum of overlapping. Wettable powders of benzene hexachloride (10 per cent gamma isomer) and DDT (50 per cent) were used as base materials.[2] These chemicals were applied as water suspensions at rates of one-half, 1 and 2 pounds of gamma benzene hexachloride and 5 and 10 pounds of actual DDT per acre. All five sprays were used at a rate of 100 gallons per acre. To avoid contamination during plowing and cultivation and to reduce possible errors at harvest time, untreated alleys 10 feet wide separated each of the plots.

In the side-dressing experiment, located

[2] *Gammex-10 W.* Pennsylvania Salt Manufacturing Company, Philadelphia, Pa.
Powco 50 Per cent DDT Wettable. John Powell and Company, Inc., New York, N. Y.

in the same cornfield, each treatment was replicated three times in parallel plots four rows wide and 50 feet long. A hand-operated fertilizer applicator, adjusted to deliver approximately 80 pounds of mixed dust per acre, was run down each side of the corn row, depositing a narrow band of insecticide 2 to 3 inches below the surface and 4 to 5 inches from the base of the plants. The same basic materials as those used in the pre-plowing test, were diluted with pyrophyllite to form 1, 2 and 3 per cent gamma benzene hexachloride mixtures and 6 and 12 per cent DDT dusts. These formulations were applied on June 10 at the rates of approximately 0.8, 1.6 and 2.4 pounds of the gamma benzene hexachloride and 4.8 and 9.6 pounds of actual DDT per acre.

Three methods were used in measuring the experimental results. First, counts were taken of rootworms in samples of roots and soil from each plot; second, root injury was estimated by recording the number and degree of stalk lodging and third, yield records were obtained. The data have been analyzed statistically for significance.

On July 31, a number of stalks selected at random were cut off at the base and samples consisting of the roots and surrounding soil 7 inches square by 5 to 6 inches deep, were then carefully removed and placed in paper bags. Three samples were taken from each plot of the pre-plowing test and two from each plot in the side-dressing experiment. These were taken to the laboratory for examination and the number of larvae, pupae and newly emerged adults, were recorded.

The first readings on the number of stalks lodged, leaning or "bowing" were also made on July 31. Injury at this time was evidenced mainly by loose stalks or stalks with a slight bend at the very base of the plant, referred to as "bowing." On October 16, at the time of harvest, lodging was extensive in some plots and records were made of stalks leaning 30 degrees or more from the vertical position and those down 60 degrees or more. Yields were obtained by harvesting all the corn by hand from four 18-foot strips, four rows wide in each plot of the pre-plowing test and from a 36-foot strip of all four rows in each plot of the side-dressing experiment. Moisture determinations were obtained electrolytically by the University of Nebraska, Department of Agronomy.

Another soil insecticide test was conducted in 1947 at the University Experiment Station, North Platte, Nebraska, on a series of corn plots under dry-land farming conditions.[1] The plots were part of a rotation experiment that has been conducted for several years. Plots of corn following corn were treated with a benzene hexachloride spray at rates of 0.7 and 2.0 pounds of the gamma isomer per acre. Each of the treatments was replicated in four or five different plots. The spray was directed toward the surface of the soil along the rows of corn just prior to the first cultivation on June 24. Care was taken not to spray the plants directly. Applications were made at low pressures with a spray gun operating from a power sprayer.

Soil samples for insect records were not taken in this test. Result readings were confined to counts of damaged stalks and yields. Records of root damage, as evidenced by loose stalks, were obtained from the two center rows of each plot on August 21. Estimates of stalk damage also were made on four plots that had been in winter wheat in 1946. These data coupled with yield records add to the information regarding the value of rotations as a control measure for rootworms. General observations in the corn plots during August and September indicated that the rootworm population was relatively light.

RESULTS.—Data collected from the soil insecticide tests at Lexington have been summarized in tables 3 and 4. Benzene hexachloride gave good control of rootworms in both experiments as evidenced by the number of rootworms found in soil samples and by the percentage of stalks lodged. DDT at the concentration tested was relatively less effective.

In the pre-plowing test (Table 3) the three benzene hexachloride treatments did not differ significantly. All were superior to the two DDT treatments and checks with respect to kill of the insects and reduction in amount of "bowing" and lodging. Similar statements may be made for the side-dressing experiment. Although the variance among insect readings was large, the data indicate excellent control of the rootworms with benzene hexachloride and a correspondingly less effective con-

[1] This test was conducted by L. L. Zook, agronomist, and Glen Viehmeyer, horticulturist, of the North Platte Experiment Station. The authors acknowledge permission to obtain damage records and use yield data from the test.

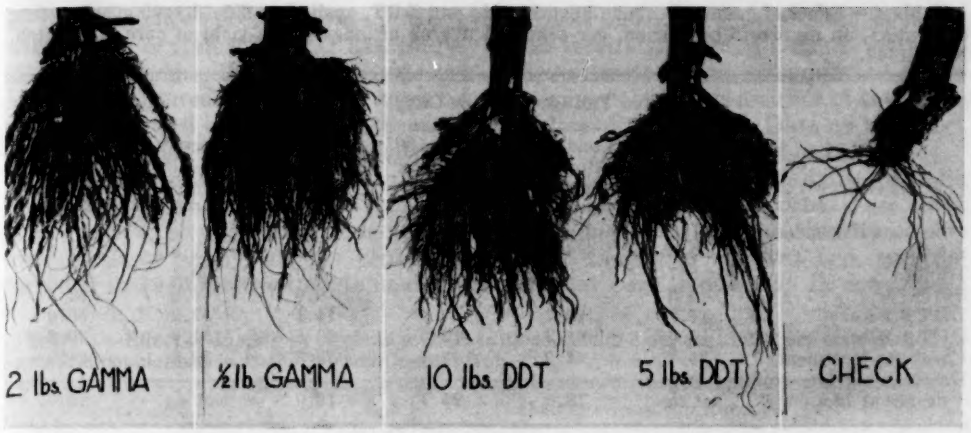

FIG. 3.—Differences in root growth following insecticidal kill of rootworms. Photographed August 8, 1947.

trol with DDT. Toxicity of the insecticides to rootworms was also evidenced by differences in stalk and root growth on August 8 (Figs. 2 and 3). Significantly less lodging occurred in benzene hexachloride plots. Some reduction in early lodging or "bowing" was evident where 9.6 pounds of DDT were used and the per cent down 60 degrees or more at harvest time was significantly lower than the checks.

Yields results were not as striking. In the pre-plowing test total yield differences were not statistically significant. Soil variations appeared to mask the effects of the insecticide treatments. Actual yields from plots sprayed with benzene hexachloride averaged from 2 to 10 bushels per acre more than those from the untreated plots, whereas DDT increased yields from 0.5 to 3 bushels.

Corn, lodged 60 degrees or more cannot be harvested satisfactorily with mechanical pickers, so it seemed desirable to correct yields for this factor. When this correction was made, yields in the pre-plowing test were shown to have been increased on an average from 11.7 to 19.6 bushels per acre by benzene hexachloride and in DDT treated plots the increase amounted to 7.3 to 10.4 bushels per acre.

Actual yield increases in the side-dressing experiment likewise were not statistically significant; however, the trend was very interesting (Table 4). Benzene hexachloride increased the yields from 10.6 to 19.7 bushels per acre, whereas plots treated with 4.8 pounds of DDT yielded less than the untreated checks and an increase of only 5 bushels was obtained with 9.8 pounds of DDT. When yields were corrected for the "down stalks," as mentioned above, the differ-

Table 3.—Effect of gamma benzene hexachloride and DDT, applied as sprays before plowing, on rootworm population, per cent and degree of lodging and yield of corn. Lexington, Neb., 1947.

TREATMENT	NO. ROOTWORMS PER SAMPLE (JULY 31)	PER CENT STALKS LODGED OR "BOWING" (JULY 31)	PER CENT STALKS LODGED 30° OR MORE (OCT. 16)	PER CENT STALKS DOWN 60° OR MORE (OCT. 16)	ACTUAL YIELD BU.[1] PER ACRE	CORRECTED YIELD BU. PER ACRE
γ-Benzene Hexachloride						
2 lbs.	0.8	2.3	1.0	0.0	55.9	55.9
1 lb.	4.6	2.7	2.1	0.0	63.8	63.8
0.5 lb.	6.1	5.7	5.4	0.0	60.3	60.3
DDT–10 lbs.	12.2	36.0	26.6	4.1	53.6	51.5
DDT–5 lbs.	17.4	34.7	38.8	4.0	56.7	54.6
Check (no treatment)	22.4	50.7	66.7	19.1	54.0	44.2
Diff. required for significance at 19:1 odds	6.0	21.1	14.5	6.3	not sig.	not sig.

[1] Calculated on the basis of 15.5 per cent moisture.

Table 4.—Effect of gamma benzene hexachloride and DDT, applied as side-dressing before first cultivation, on rootworm population, per cent and degree of lodging and yield of corn. Lexington, Neb., 1947.

Treatment	No. Rootworms per Sample (July 31)	Per Cent Stalks Lodged or "Bowing" (July 31)	Per Cent Stalks Lodged 30° or More (Oct. 17)	Per Cent Stalks Down 60° or More (Oct. 17)	Actual Yield Bu.[1] per Acre	Corrected Yield Bu. per Acre
γ-Benzene Hexachloride						
2.0 lbs.	5.8	2.0	2.1	0.0	71.9	71.9
1.6 lbs.	8.7	8.3	4.4	0.0	69.2	69.2
0.8 lb.	14.3	7.3	6.8	0.0	62.8	62.8
DDT 9.6 lbs.	17.7	29.7	57.9	14.1	57.2	50.0
DDT 4.8 lbs.	18.0	64.3	72.0	26.8	51.6	39.3
Check (no treatment)	25.7	61.7	77.7	35.8	52.2	34.8
Dif. required for significance at 19:1 odds	not sig.	13.0	25.7	18.0	not sig.	20.7

[1] Calculated on the basis of 15.5 per cent moisture.

ences were found to be significant. Bushel increases of 28.0, 34.4 and 37.1 per acre were recorded from plots receiving 0.8, 1.6 and 2.4 pounds of γ-benzene hexachloride per acre, respectively. Increases of 4.5 and 15.2 bushels were recorded from plots treated with 4.8 and 9.6 pounds of DDT, respectively.

Results of the dry-land study are summarized in table 5. Stalk lodging in untreated corn following corn was significantly greater than where corn followed winter wheat or was treated with benzene hexachloride. However, the yields failed to differ. This was rather surprising for in 1946 corn after corn yielded 14.5 bushels as compared to 24.6 for corn following wheat. Mr. L. L. Zook, agronomist, in charge of these corn rotation experiments for several years, believed the reduction in yield of corn after corn in 1946 was due to rootworm. Unfortunately, we have no data with which to compare the 1946 and 1947 insect infestations.

Table 5.—Effect of previous crop and benzene hexachloride, applied by spray before first cultivation, on per cent stalks damaged and yield of corn on nonirrigated rotation plots. North Platte, Neb., 1947.

1946 Crop	Treatment[1]	Per Cent Stalks Damaged[2]	Yield Bu. per Acre
Corn	0.7 lb. γ-benzene hexachloride	16.4	29.2
Corn	2.0 lb. γ-benzene hexachloride	16.3	28.9
Corn	None	54.2	28.3
Winter Wheat	None	18.5	32.6

[1] Per acre basis.
[2] Based on sample counts of loose, leaning or down stalks, Aug. 21, 1947.

AERIAL INSECTICIDE TREATMENTS.—Although insecticide applications on corn plants for the control of insects have long been suggested, they were not, until the discovery and development of the synthetic chlorinated insecticides, considered financially practical. Since the development of DDT and related chemicals, many investigations have been conducted. Spraying and dusting tests on corn include those of Luginbill & Benton (1945) who obtained control of chinch bugs with a 1 to 5 per cent DDT dust in pyrophyllite, Poos (1945) who controlled the corn flea beetle with a spray of 0.66 per cent DDT, Batchelder & Questel (1945) who obtained some control of the European corn borer with several dusts and sprays of DDT, Blanchard *et al.* (1946) who obtained control of fall army worms with a DDT spray but found dusts containing 9 per cent or less of DDT to be ineffective, Decker *et al.* (1947) and Bigger *et al.* (1947) who obtained control of the European corn borer on canning and field corn, respectively, with sprays and dusts of DDT. Decker *et al.* (1947) found that residues were lower from dusts than from solutions and emulsions, an observation which may have some bearing on the feeding of crop remnants to livestock.

Late in the summer of 1946, irrigation farmers in central Nebraska became alarmed by the silk feeding activity of the western corn rootworm and consulted the Entomology Department for recommendations. The usual recommendation of crop rotation was given, but,

at the insistence of the growers, dusting with a 3 per cent dust of DDT at a rate of 25 to 30 pounds to the acre was suggested for trial. Approximately 5000 acres of corn were dusted by airplane in the area.

Procedure and Results.—Pre-treatment and post-treatment records were made on several fields in 1946 and observations and surveys were conducted in 1947. Kills of nearly 100 per cent were recorded in 1946 for treatments made on August 8, 10 and 18. Migrant and newly emerged adults were observed surviving in treated fields 5 to 7 days following treatment. Table 6 gives the records and observations for nine fields during 1946 and 1947.

Table 6.—Effect of dusting by airplane with 25 to 30 pounds of 3 per cent DDT per acre in 1946 on rootworm populations in 1947. Dawson County, Neb.

Field			Observations and Records				
			1946			1947	
No.	Acres	Years Corn Prior to 1946	(Aug. 15) Est. Adults per Plant	Per Cent Injury Stalks Lodging	No. Treatments	(Aug. 19) Est. Adults per Plant	Per Cent Injury Stalks Lodging
1	40	1	20 to 40	30	1	2 to 4	None
2	100	1	35 to 40	30	2	None	None
3	80	3	———	10	1	2 to 4	None
4	40	?	———	Reported heavy	1	12 to 14	None[1]
5	40	?	———	Reported heavy	1	−1	None
6	40	?	———	Reported heavy	1	−1	None
7	60	?	———	Reported heavy	1	None	None
8	40	0	———	Reported light	0	4 to 12	None[1]
9	80	1	———	Reported light	0	3 to 4	None[1]

[1] Although no stalks were lodged in these fields, due apparently to deep listing, injured or loose stalks were counted. The loose stalks amounted to 27 to 29 per cent in field 4, 8 per cent in field 8 and 18 per cent in field 9.

An experiment with airplane dusting with DDT was undertaken in 1947 to determine the adult kill, the possibility of increased yield due to reduction in silk feeding and proper timing of the treatment.

A 30-acre field infested with the western corn rootworm and the northern corn rootworm was used. Adults were counted before treatment and found to vary from 10 to 40 per plant with an average of 20. Pre-treatment counts on damaged or lodged stalks were made and found to average 38 per cent for the entire field. Ten acres were treated on August 21, 1947 with 3 per cent DDT in pyrophyllite at a rate of 30 pounds to the acre, 10 acres were treated on August 30, 1947 with the same mixture and dosage and 10 acres were left untreated.

Adult mortality counts made 24 hours after treatment showed a 99 per cent kill. Harvest records gave no significant differences in yield between either of the treatments and the control. Data on the effect of timing will be collected in 1948.

SUMMARY AND CONCLUSIONS.—Results of field experiments reported here show that injury by both the western corn rootworm, *Diabrotica virgifera* Lec. and the northern corn rootworm, *D. longicornis* (Say), as evidenced by stalk lodging, was greatly reduced in irrigated cornfields when corn was grown in rotation following sweet clover or treated with nitrogen fertilizers. Furthermore, the use of a nitrogen fertilizer, manure or a leguminous crop in the rotation system greatly increased yields. Nitrogen did not appear to affect rootworm populations, but did hasten root recovery, reduce lodging and increase the yield. Phosphorous had no effect on yield or lodging.

Soil applications of benzene hexachloride at rates of one-half, 1 or 2 pounds of gamma isomer per acre sprayed on the surface before plowing, or 0.8, 1.6 or 2.4 pounds applied as side-dressings just prior to the first cultivation, greatly reduced rootworm populations and almost eliminated root injury and lodging. Technical DDT applied in the same manner at rates of 5 or 10 pounds per acre was either no better or only slightly superior to the untreated checks. Yields were not significantly increased by any of the insecticide treatments. However, when corrections

were made to eliminate ears produced on stalks lodged 60 degrees or more (ears which would ordinarily be missed by mechanical pickers) plots treated with benzene hexachloride as side-dressings were shown to have produced significantly higher yields.

Under dry-land conditions stalk damage, indicated by lodging and root loss, was significantly greater in plots where corn followed corn than where corn followed wheat. Corn after corn on soil sprayed prior to the first cultivation with 1 pound gamma benzene hexachloride also had significantly less stalk lodging. Yields did not differ.

Aerial applications of 3 per cent DDT dusts applied at the rate of 25 to 30 pounds per acre gave excellent kills of rootworm adults. Field observations indicated that such treatments reduced rootworm populations so effectively that lodging was of little consequence during the immediate succeeding season.

The data presented in this paper do not show measurable increases in yield due to corn rootworm control. Neither did a review of the literature produce information suggesting that actual control would increase yields. In fact, every measurable yield increase so far reported could have been due to the addition of some plant nutrient to the soil, especially nitrogen, either as commercial fertilizers, manure or by legumes in rotations. Although the benzene hexachloride treatments used in the present study tended to increase actual yields, the increases were not statistically significant.

It appears that available nitrogen in the soil is the key to large corn yields and root recovery and that rootworm injury, as such, may be a minor factor in reducing yields. Nevertheless the difficulty and losses experienced by farmers attempting to harvest ears from lodged and fallen stalks is serious. It is evident that this difficulty and loss can be materially reduced, if not eliminated, by proper rotations, applications of nitrogen fertilizers or insecticidal treatments. Much additional research on insecticidal treatment is needed. Questions that remain unanswered include the following: will reduction of rootworm populations affect actual corn yields; will chlorinated insecticides prove harmful to soil micro-organisms; will combinations of insecticides and fertilizers be feasible; what method and time of application will be most effective?—2-26-48.

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Control of Boll Weevil and Cotton Aphid with Benzene Hexachloride and Chlorinated Camphene in 1947

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Investigations at Tallulah, La., were continued with several concentrations of benzene hexachloride and chlorinated camphene in 1947. An experiment was made to determine the effectiveness of these materials when applied at different times of day and at different intervals between applications for control of the boll weevil, *Anthonomus grandis* Boh., and the cotton aphid, *Aphis gossypii* Glov. The addition of one application of the highest concentration of either benzene hexachloride or chlorinated camphene to the regular calcium arsenate dusting program was included in the experiment. The treatments were compared with calcium arsenate alone and with the standard treatment of alternate applications of calcium arsenate alone and with nicotine. Untreated plots were used as checks. The effect of the various treatments upon the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, was also determined.

Plots 0.1 acre in size were arranged in 4 randomized blocks. There were 36 treatments and 4 replications of each treatment. The benzene hexachloride mixtures containing 5, 2.5, and 1.25 per cent of the gamma isomer and mixtures containing 20, 10, and 5 per cent of chlorinated camphene were applied early in the morning (5 to 8 a.m.) and late in the afternoon (5 p.m. to dark) at 4- or 5- and at 7- to 9-day intervals. The alternate applications of calcium arsenate and a nicotine-calcium arsenate mixture and the applications of calcium arsenate alone were made at 4- or 5-day intervals early in the morning and late in the afternoon. Early morning applications of calcium arsenate with benzene hexachloride (5 per cent of the gamma isomer) at the first, second, third, or fourth application, and of calcium arsenate with 20 per cent of chlorinated camphene at the first, third, or fourth application were made at 4- or 5-day intervals. All applications were made with rotary hand-dusting machines.

All mixtures were prepared at the laboratory several weeks before applications were begun. The lower concentrations of benzene hexachloride and chlorinated camphene were prepared by mixing the proper amount of diluent with commercial mixtures containing benzene hexachloride (5 per cent of the gamma isomer) or 20 per cent of chlorinated camphene. For the calcium arsenate-nicotine mixture the proper quantity of a commercial nicotine dust concentrate was mixed with standard calcium arsenate to give a mixture containing 2 per cent of actual nicotine.

The plots treated at 7 to 9-day intervals were dusted on July 16, 23, 30, and August 8, and those treated at 4- or 5-day intervals on July 16, 21, 25, and 30, and August 4 and 8. All the dusts remained on the cotton plants for 24 hours or longer before rainfall occurred. Treat-

[1] Thanks are due G. L. Garrison, S. C. Bray, H. L. LeBlanc and Carroll Crow for assistance in obtaining the records. The experiment was conducted under the general direction of R. G. Gaines.

Table 1.—Effect on insect infestations and yield of cotton of benzene hexachloride, chlorinated camphene, calcium arsenate with and without nicotine, and calcium arsenate plus one application of either benzene hexachloride or chlorinated camphene. Average dosage, 6.8 to 9.5 pounds per acre-application.

Treatment	Boll Weevil Infestation		Aphids per Square Inch	Spider Mites per Square Inch	Blooms per Acre	Yield of Seed Cotton per Acre	
						Total	Increase over Check
	Per Cent	*Angle*	*Number*	*Number*	*Number*	*Pounds*	*Pounds*
Benzene hexachloride (a.m. and p.m.):							
7- to 9-day intervals:							
5% gamma	29	33	0.07	5.5	1609	1717	26
2.5% gamma	36	37	.17	6.0	1808	1654	−37
1.25% gamma	41	40	.55	3.8	2055	1612	−79
4- to 5-day intervals:							
5% gamma	24	29	.06	7.4	3559	1895	204
2.5% gamma	30	33	.14	7.6	2153	1880	189
1.25% gamma	36	37	.15	7.0	3326	1722	31
Chlorinated camphene (a.m. and p.m.):							
7- to 9-day intervals:							
20%	39	39	.43	4.0	2869	1796	105
10%	44	42	.78	8.3	1770	1649	−42
5%	47	43	.88	4.7	1560	1659	−32
4- to 5-day intervals:							
20%	32	34	.21	3.2	3818	1906	215
10%	39	39	.33	3.7	2021	1874	183
5%	47	43	.62	3.0	1410	1717	26
Calcium arsenate 4- to 5-day intervals.							
Alone (a.m. and p.m.)	30	33	5.18	1.9	7448	1935	244
Alone and with nicotine 2% alternate applications (a.m. and p.m.)	30	33	.54	1.5	4961	1953	262
Plus one application of benzene hexachloride (gamma isomer 5%) (a.m.)	27	31	1.29	2.0	5775	2001	310
Plus one application of chlorinated camphene 20% (a.m.)	30	33	2.68	2.1	5770	1925	234
Check (no treatment)	49	44	1.36	3.1	1020	1691	
Minimum significant difference at 5% level	—	5	.77	—	2738	188	

ments were started when approximately 25 per cent of the squares were infested with boll weevils. Boll weevil square infestations were determined weekly from July 14 to August 5 by examining 100 squares in each plot. The boll weevil infestations presented in table 1 are averages of records made on July 22, 28, and August 5. Aphid infestations were determined by counting the aphids on 1 square inch of the underside of the fourth leaf from the top of the plant on 100 plants in each plot at weekly intervals. The aphid counts presented in the table are averages of records made on 9 dates from July 18 to September 3. The two-spotted spider mites were counted on 2 blocks in the same manner as the cotton aphids, except that only 20 square inches were examined in each plot of block 1 on August 15 and 40 square inches in each plot of block 4 on August 19 and 20. The blooms were counted on the four center rows of each plot on August 13 and 14. Yields were obtained by picking the bolls from the 4 center rows of each plot.

The treatments with (1) benzene hexachloride, (2) chlorinated camphene, (3) alternate applications of a nicotine-calcium arsenate mixture and calcium arsenate, and (4) calcium arsenate alone were all equally effective against the boll weevil and the cotton aphid whether applied early in the morning or late in the afternoon; so the records obtained at both times of day were averaged in table 1.

The three benzene hexachloride dusts were more effective against both the boll weevil and the cotton aphid and caused a greater increase in yield when applied at 4- or 5-day intervals than when applied at 7- to 9-day intervals. At 4- or 5- day intervals they gave better cotton aphid control than the alternate applications

of the calcium arsenate-nicotine mixture and calcium arsenate. The benzene hexachloride dusts containing 5 and 2.5 per cent of the gamma isomer gave boll weevil control equal to that of calcium arsenate or alternate applications of the calcium arsenate-nicotine mixture and calcium arsenate, but neither of the benzene hexachloride dusts yielded so well.

The dusts containing 20 and 10 per cent of chlorinated camphene were more effective against the boll weevil and the cotton aphid and yielded better when applied at 4- or 5-day intervals than when applied at 7- to 9-day intervals. However, neither the boll weevil control nor the yields from any of the chlorinated camphene dusts were so good as those from either calcium arsenate or alternate applications of the calcium arsenate-nicotine mixture and calcium arsenate.

Five applications of calcium arsenate plus one application of benzene hexachloride (5 per cent of gamma isomer) gave better boll weevil control and a greater yield than alternate applications of the calcium arsenate-nicotine mixture and calcium arsenate, but the aphid control was not so good. The benzene hexachloride mixture containing 5 per cent of the gamma isomer, when used as a separate application with calcium arsenate in the boll weevil control program, gave better aphid control than 20 per cent chlorinated camphene used in a similar way in the calcium arsenate program. Both benzene hexachloride and the chlorinated camphene permitted an increase of two-spotted spider mites. The greatest increase was noted where benzene hexachloride was used. Where benzene hexachloride (5, 2.5, and 1.25 per cent of gamma isomer) or chlorinated camphene (20, 10, and 5 per cent) was used for all applications, the cotton was much lighter in color during August and did not bloom so well as did the cotton that was treated with calcium arsenate, the calcium arsenate-nicotine mixture, or calcium arsenate plus one application of either benzene hexachloride (5 per cent of gamma isomer) of 20 per cent chlorinated camphene. Some burning of the cotton foliage was noted from the benzene hexachloride containing 5 per cent of the gamma isomer.

Cage Tests Against the Boll Weevil and the Tarnished Plant Bug with Synthetic Organic Insecticides and Calcium Arsenate in 1947

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Several organic insecticides and calcium arsenate were tested in cages against the boll weevil, *Anthonomus grandis* Boh., and the tarnished plant bug, *Lygus oblineatus* (Say). The organic materials tested were chlordan, benzene hexachloride, chlorinated camphene, parathion (0, 0-diethyl 0-*p*-nitrophenyl thiophosphate), DDT, and the methoxy analog of DDT. The tests were made in 1947 at the Tallulah, La., laboratory of the Bureau of Entomology and Plant Quarantine.

The method of conducting cage tests was briefly as follows: A cloth hood 4 by 4 by 4 feet was placed over a cotton plant. The dust was then discharged into the hood. The hood was allowed to remain over the plant for several minutes. All the insecticides and mixtures were applied at the rate of 8 pounds per acre. Screen-wire cages measuring 1.5 by 1.5 by 2 feet were used in the tarnished plant bug tests. Two types of cages (1.5 by 1.5 by 2 feet and 4 by 4 by 4 feet) were used in the boll weevil tests. After the cages were placed over the cotton plants, the insects were released in them immediately or shortly after the dusting was completed. The plants were not redusted in case of rain. Counts for dead and live insects were usually continued for 4 days; however, in some cases, the period was shorter. The net mortalities given in tables 1 to 3 were computed by Abbott's formula.

The boll weevils were obtained from the

[1] Thanks are due R. L. Moncrief, C. M. Medlin, J. M. Monsell, and T. L. Rosenzweig for assistance in obtaining the records. The tests were conducted under the general direction of R. C. Gaines.

field with sweep nets and "bug-catching" machines, or were reared in the insectary. Only a small number from the insectary were used, and these were placed on the cotton plants for 24 hours or more, where they fed before they were mixed with the other boll weevils. The tarnished plant bugs were collected with sweeping nets on *Erigeron annuus*. Ten to 25 boll weevils and 25 tarnished plant bug adults were used per cage.

Three series of tests were made. In the first series three concentrations of parathion, chlordan, chlorinated camphene, and benzene hexachloride were tested against both insects. The tests against the tarnished plant bug were conducted between June 30 and July 18. All dusts were applied while the cotton plants were dry and when temperatures ranged from 84 to 96° F. Rainfall of 0.12 inch and 0.95 inch occurred during two different sets of tests. Five sets of tests were conducted against the boll weevil between July 14 and August 25. In three sets the dusts were applied while the plants were wet with dew and when temperatures ranged from 72 to 77°. Rainfall occurred on four of the five sets of tests. On the first set 0.95 inch was recorded, and on the third a total of 0.84 inch fell on three dates. Rainfall on the fourth and fifth sets of tests was 0.03 and 0.02 inch, respectively. All dusts except parathion were prepared in the laboratory by mixing a diluent with commercial preparations containing 20 per cent of chlordan, 20 per cent of chlorinated camphene, or benzene hexachloride (5 per cent of the gamma isomer). The three mixtures of parathion were commercial preparations.

Table 1.—Mortality of tarnished plant bugs and boll weevils treated with parathion, chlordan, chlorinated camphene, and benzene hexaride, and of boll weevils treated with calcium arsenate. (15 replications.)

Treatment	Tarnished Plant Bugs	Boll Weevils
	Per Cent	*Per Cent*
Parathion:		
2%	82	31
1%	36	25
0.5%	17	13
Chlordan:		
20%	60	67
10%	18	43
5%	8	22
Chlorinated camphene:		
20%	82	79
10%	31	57
5%	22	34
Benzene hexachloride:		
5% gamma	89	68
2.5% gamma	70	49
1.25% gamma	39	36
Calcium arsenate	—	68
Minimum significant difference at 5% level	17	18

The results of these tests are given in table 1. The mortalities in the untreated check cages averaged 23 per cent for the tarnished plant bug and 20 per cent for the boll weevil. The highest concentration of each organic insecticide gave an average net mortality of tarnished plant bugs significantly greater than any of the lower concentrations. Chlordan was not so effective as the other materials. In tests against the boll weevil, dusts containing 20 per cent of chlordan, 20 per cent of chlorinated camphene, and benzene hexachloride (5 per cent of the gamma isomer), were as effective as calcium arsenate whereas lower concentrations of the three organic compounds were less effective, in most cases significantly so. Parathion was much less effective than any of the other materials tested. Gaines & Young (1947) have reported that there is a highly significant correlation between the percentage of gamma isomer in the benzene hexachloride mixtures and the net mortality of both tarnished plant bugs and boll weevils. Table 1 shows that there is a definite relation between the amount of active ingredient of all the organic insecticides tested and the net mortalities of the two insects.

The second series of tests was conducted against tarnished plant bugs during the latter part of July and early in August. Tests against the boll weevil were started on seven dates from August 5 to 27. Total rainfall of 1.80 inches was recorded on seven dates between August 10 and August 25. The mortalities in the untreated check cages averaged 14 per cent for the tarnished plant bug and 17 per cent for the boll weevil. The materials tested were commercial preparations containing DDT, benzene hexachloride, chlorinated camphene, chlordan, or parathion. Ten mixtures of these materials prepared in the laboratory were also tested.

The treatments used and the results

Table 2.—Mortality of tarnished plant bugs and boll weevils on plants dusted with calcium arsenate, DDT, benzene hexachloride, chlorinated camphene, chlordan, and parathion, and 10 mixtures of these materials.

TREATMENT	TARNISHED PLANT BUGS[1]	BOLL WEEVILS[1]
	Per Cent	*Per Cent*
DDT 5%		
Alone	75	15
Plus benzene hexachloride, 3% gamma	98	54
Plus chlorinated camphene 10%	97	58
Plus chlordan 10%	94	50
Plus parathion 2.5%	97	45
Benzene hexachloride, 3% gamma:		
Alone	96	37
Plus chlorinated camphene 10%	94	56
Plus chlordan 10%	99	55
Plus parathion 2.5%	98	56
Chlorinated camphene 10%:		
Alone	74	41
Plus chlordan 10%	93	56
Plus parathion 2.5%	94	62
Chlordan 10%:		
Alone	56	34
Plus parathion 2.5%	98	62
Parathion 2.5%	98	42
Calcium arsenate	35	49
Minimum significant difference at 5% level	19	20

[1] Net mortalities based on 6 replications for the tarnished plant bug and on 16 replications for the boll weevil.

Table 3.—Mortality of tarnished plant bugs and boll weevils treated with several commercial mixtures of benzene hexachloride, methoxy analog of DDT, and chlordan, and of boll weevils treated with calcium arsenate. (12 replications.)

TREATMENT	TARNISHED PLANT BUGS	BOLL WEEVILS
	Per Cent	*Per Cent*
Benzene hexachloride:		
6% gamma	85	45
3% gamma, 5% DDT, 40% sulfur	83	39
3% gamma, 5% DDT, 40% inert	86	25
3% gamma, 5% DDT	77	46
Methoxy analog of DDT, 50%	43	52
Chlordan:		
5%	6	21
10%	11	29
20%	66	76
10%+5% DDT	84	56
5%+5% DDT	69	49
Calcium arsenate	—	56
Minimum significant difference at 5% level	15	27

obtained in these tests are reported in table 2. Against the tarnished plant bug all treatments gave average net mortalities significantly greater than calcium arsenate. The 10 mixtures, benzene hexachloride (3 per cent of the gamma isomer), and 2.5 per cent of parathion, were equally effective, and all gave average net mortalities significantly greater than did 10 per cent of chlordan. Against the boll weevil, with the exception of 5 per cent DDT, all the organic insecticides and mixtures of these insecticides were equal in effectiveness to calcium arsenate.

The third series of tests was conducted against tarnished plant bugs from July 7 to 23 and against boll weevils between July 15 and August 11. Rainfall recorded during the first and last sets of tests was 1.90 inches and 0.17 inch, respectively. Dust applications were made in the late afternoons when the plants were dry, and the temperatures ranged from 82 to 98° F. The average mortality in the check cages was 42 per cent for boll weevils and 20 per cent for tarnished plant bugs. Old age or injury may have accounted for the high mortalities in the checks, as the boll weevils used in 6 of the 12 replications were collected with bug-catching machines. Commercial dusts were used in these tests.

Table 3, which gives the results of these tests, shows that against tarnished plant bugs the three mixtures of benzene hexachloride and DDT were equal in effectiveness to benzene hexachloride alone. The mixture containing 10 per cent of chlordan and 5 per cent of DDT gave the highest average net mortality of any of the chlordan dusts tested. The low mortalities caused by the 5 and 10 per cent chlordan were probably due to the poor dusting qualities of the two samples. Against the boll weevil, 20 per cent of chlordan, a mixture of 10 per cent of chlordan and 5 per cent of DDT, and calcium arsenate gave the highest net mortalities, and all were equally effective.—5-3-48.

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Bollworm Control with Chlorinated Camphene, DDT, and Mixtures of Benzene Hexachloride and DDT

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The bollworm, *Heliothis armigera* (Hbn.), is probably the most difficult cotton insect to control. There are many factors influencing bollworm populations, damage, and control. Some of these factors have previously been discussed (Ewing & Ivy 1943). In recent years many cotton growers and entomologists have observed that increased cotton aphid *Aphis gossypii* Glov. and bollworm infestations often follow mid-season dusting of cotton with calcium arsenate for boll weevil control. Injury from these increased infestations frequently results in losses equal to or greater than those which would have been caused by the boll weevil if the calcium arsenate had not been used. This is one of the main reasons why more cotton growers have not used calcium arsenate for boll weevil control.

Calcium arsenate has been used for bollworm control, but it is not as toxic as it should be to give full protection against this insect (Gaines & Dean 1947). Experiments at Waco, Tex., have shown that, against severe infestations of bollworms, heavy applications of calcium arsenate were only about one-half as effective as a mixture containing 5 per cent of DDT and enough benzene hexachloride to bring the gamma isomer content to approximately 3 per cent (Ewing *et al.* 1947). A dust containing 10 per cent of DDT in an inert diluent, or in sulfur, controlled the bollworm but did not control boll weevils, *Anthonomus grandis* Boh., or cotton leafworms, *Alabama argillacea* (Hbn.), and its use usually resulted in increased aphid infestations. In laboratory, cage, and field tests conducted at Waco in 1946, promising results were obtained with a dust containing 20 per cent of chlorinated camphene against the more important cotton insects, including the bollworm (Ivy *et al.* 1947). Like calcium arsenate, benzene hexachloride, DDT, a combination of the two, and chlorinated camphene destroy certain kinds of beneficial insects that feed on bollworm eggs and larvae, and when used in mid-season, or just prior to bollworm infestation, they may result in increased bollworm infestations. It is therefore very important that an economical insecticide be found that will give satisfactory kill of the bollworm, prevent injurious aphid infestations, and at the same time control other late-season insects, such as the boll weevil and cotton leafworm.

This paper describes results of two small-plot and six large-scale field experiments conducted at Waco in 1947 to compare the effectiveness against the bollworm of DDT, calcium arsenate, different concentrations and mixtures of chorinated camphene (67–69 per cent of chlorine), and mixtures of DDT and benzene hexachloride.

The plots in the small-plot experiments were 10 rows wide, 0.1 acre in size, and arranged in randomized blocks with 4 replications of each treatment. The plots in the large-scale experiments ranged in size from 1 to 10 acres. The small plots were dusted with rotary hand dust guns and the large plots with power-take-off, 6- or 8-row tractor-attachment dusting machines. The procedure and method of recording data were the same as had been previously reported (Ewing & Parencia 1943). In each experiment all treatments were applied at approximately the same rate. Boll weevils and cotton flea-hoppers did not become sufficiently numerous to cause appreciable damage in any of the experiments. The treatments and experimental data are shown in table 1.

The chlorinated camphene used in the small-plot experiments was a commercial dust containing 40 per cent of active ingredient in a clay product.[2] This dust was diluted with various proportions of prophyllite or sulfur in a mixing machine at the laboratory. In the large-scale experiments a commercial dust containing 20 per cent of chlorinated camphene, 30 per cent of clay, and 50 per cent of pyrophyllite was used. Further dilutions were

[1] In cooperation with the Texas Agricultural Experiment Station.

[2] *Attaclay.*

Table 1.—Comparative effectiveness of chlorinated camphene, DDT, mixtures of DDT and benzene hexachloride, and calcium arsenate against bollworms in field experiments at Waco, Tex., 1947.

Treatment	Rate of Application per Acre	Bollworm Infestation		Aphids per Square Inch		Yield of Seed Cotton per Acre	
		Injured Squares	Injured Bolls	Average	Maximum	Total	Gain Over Check
	Pounds	*Per Cent*	*Per Cent*	*Number*	*Number*	*Pounds*	*Pounds*
Small-plot experiment 1 (3 applications, July 18, 22, and 29)							
Chlorinated camphene 20%	16	5	4	0.2	0.5	834	19
Benzene hexachloride, gamma 3%, plus DDT 5% plus sulfur 20%	17	5	3	0.1	0.2	850	35
DDT 10% plus sulfur 80%	20	4	3	0.2	0.4	928	113
DDT 10% in pyrophyllite	18	4	2	0.8	2.6	886	71
Calcium arsenate	19	7	6	1.2	4.4	800	−15
Untreated check	—	9	10	0.2	0.7	815	—
Difference required for significance, 5% level	—	—	2.4	0.6	—	—	—
Small-plot experiment 2 (3 applications, July 29, August 2 and 7)							
Chlorinated camphene:							
20% plus sulfur 50%	18	3	3	0.01	0.02	780	118
10% plus sulfur 50%	16	5	5	0.02	0.10	741	79
10% plus DDT 5% plus sulfur 50%	17	4	2	0.03	0.08	808	146
Benzene hexachloride, gamma 3%, plus DDT 5% plus sulfur 20%	18	5	4	0.01	0.01	783	121
DDT 5% plus sulfur 75%	17	5	4	0.02	0.03	744	82
Untreated check	—	11	9	0.02	0.05	662	—
Difference required for significance, 5% level	—	3	1.7	—	—	100	—
Large-scale experiment 3 (7 applications, June 25 to August 7)							
Chlorinated camphene:							
20%	14	5	7	0.6	2.0	1056	366
10%	14	6	10	0.1	0.4	805	115
10% plus sulfur 50%	14	7	10	0.1	0.3	925	235
Calcium arsenate	14	4	9	7.9	27.4	756	66
Untreated check	—	1	8	1.1	6.2	690	—
Large-scale experiment 4 (5 applications, July 2 to 31)							
Benzene hexachloride:							
Gamma 3% plus DDT 5%	13	5	3	0.1	0.4	888	249
Gamma 2% plus DDT 5% plus sulfur 50%	11	4	3	0	0	886	247
Calcium arsenate	11	3	6	4.1	10.3	843	204
Untreated check	—	5	7	0.1	0.2	639	—
Large-scale experiment 5 (4 applications, July 24 to August 14)							
Chlorinated camphene 20%	16	5	4	0.1	0.1	810	190
Benzene hexachloride, gamma 3%, plus DDT 5%	15	7	4	0	0	836	216
DDT 10% plus sulfur 75%	16	5	3	0.1	0.2	937	317
Untreated check	—	14	11	0.1	0.1	620	—
Large-scale experiment 6 (4 applications, July 26 to August 9)							
Chlorinated camphene:							
20%	16	6	5	0.1	0.1	855	351
10% plus sulfur 50%	19	7	6	0	0	801	297
Calcium arsenate	12	7	8	0.2	0.3	751	247
Untreated check	—	18	11	0.1	0.1	504	—
Large-scale experiment 7 (3 applications, July 30 to August 9)							
Chlorinated camphene:							
20%	14	7	5	0.04	0.09	742	38
10% plus DDT 5% plus sulfur 50%	14	3	4	0.02	0.03	751	47
Untreated check	—	8	13	0.02	0.06	704	—
Large-scale experiment 8 (5 applications, July 31, to August 22)							
Chlorinated camphene 20%	15	5	4	0.01	0.03	868	249
DDT 10% plus sulfur 75%	15	2	3	0.15	0.40	880	261
Untreated check	—	12	12	0.02	0.04	619	—

made as desired by adding pyrophyllite or sulfur.

The DDT dusts used in the small-plot experiments were made by diluting a 50 per cent DDT dust concentrate with pyrophyllite or sulfur. In the large-scale experiments a commercially prepared dust containing 10 per cent of DDT and 75 per cent of sulfur was used. The mixtures of DDT and benzene hexachloride were obtained from various manufacturers, and their reported contents are listed in table 1. The calcium arsenate was the standard commercial product.

SMALL-PLOT EXPERIMENTS.—The boll-injury records for experiment 1 show that each dust reduced the bollworm infestation significantly below that of the check, and that the two 10 per cent DDT dusts and the benzene hexachloride-DDT mixture reduced the infestation significantly below that of calcium arsenate. The aphid infestation was significantly lower in all treatments than in the calcium arsenate treatment, except for the 10 per cent of DDT in pyrophyllite. Yields ranged from a gain over the check of 113 pounds of seed cotton per acre from the 10 per cent DDT-sulfur treatment to a loss of 15 pounds per acre from calcium arsenate, with no significant difference between treatments.

Square-injury records for experiment 2 show that each dust reduced the bollworm infestation significantly below that of the check, with no significant difference between insecticidal treatments. Each dust reduced the boll injury significantly below that of the check. The boll injury in the slots dusted with 10 per cent of chlorinated camphene plus 5 per cent of DDT was significantly lower than in those receiving the other treatments with the exception of the 20 per cent chlorinated camphene. The dusts containing 20 per cent of chlorinated camphene, chlorinated camphene plus DDT, and benzene hexachloride plus DDT each produced significant increases in yield over the untreated check, but there were no significant differences among any of the treatments.

LARGE-SCALE EXPERIMENTS.—In experiment 3 the dusts were applied on June 25 and 30 for fleahopper control. By July 10 fleahoppers were below the damage point in all the plots; therefore, the design of the experiment was changed to control the bollworm infestation that had developed. Beginning July 12, a plot that had been treated with sulfur alone received calcium arsenate. The other treatments remained the same. Five dust applications were made between July 12 and August 7. The two early treatments had little, if any, effect upon the final results of the experiment.

Serious red spider mite infestations developed in the plots treated with 20 and 10 per cent of chlorinated camphene in pyrophyllite. The 20 per cent chlorinated camphene plot was treated on July 30 with a heavy application of sulfur to prevent damage by the mite. Sulfur was not applied on the 10 per cent chlorinated camphene plot. Since this plot adjoined the plot treated with 10 per cent of chlorinated camphene in sulfur, the results showed that the addition of 50 per cent of sulfur gave satisfactory red spider mite control. The average seasonal infestation was 3.3 mites per square inch (maximum 6.7) in the plot were pyrophyllite was the only diluent and 0.1 (maximum 0.3) in the plot where sulfur was used. Some of the difference in yield between the two plots can probably be attributed to red spider mite damage.

The maximum number of aphids per square inch 3 weeks after the last dust application was 27.4 in the calcium arsenate plot, 2.0 in the plot treated with 20 per cent of chlorinated camphene, and 6.2 in the untreated check. The calcium arsenate plot was located between the untreated check and the plot treated with 20 per cent of chlorinated camphene. The aphid infestation in the untreated check and in the plot dusted with 20 per cent of chlorinated camphene was, no doubt, largely due to migration, as the infestation remained low in the two plots treated with 10 per cent of chlorinated camphene which were located at some distance from the calcium arsenate plot.

The bollworm infestation records, especially the square injury, were probably affected by the two dust applications made for fleahopper control. Yield records showed the best bollworm control from the 20 per cent chlorinated camphene and the poorest from calcium arsenate.

In experiment 4 the dusts were applied on July 2 and 7 in comparatively light dosages (8 to 9 pounds per acre) for boll weevil control. By July 7 boll weevils

were below the damage point in all plots; therefore, the design of the experiment was changed to control the infestation of bollworms that had developed. Beginning July 17 one plot, which had previously been dusted with benzene hexachloride alone, received a dust mixture containing 5 per cent of DDT plus benzene hexachloride of 3 per cent gamma isomer content. The other treatments remained the same. Other applications were made on July 21 and 31. The treatments applied on July 2 and 7 had little, if any, effect upon the final results of the experiment.

Aphid infestations built up in the calcium arsenate plot too late in the season to affect the yields. The maximum in this plot was 10.3 aphids per square inch, whereas in the plot dusted with the mixture containing 3 per cent of the gamma isomer it was 0.4. The last figure was reached some time after the last application and was due largely to migration from the adjoining calcium arsenate plot. No aphids were recorded in the plot treated with the mixture containing 2 per cent of the gamma isomer, which was located at some distance from the calcium arsenate plot. Yields indicate slightly better control of bollworms from the mixtures than from calcium arsenate, with practically no difference between the two mixtures.

In experiment 5, bollworm control was about the same for all the insecticides. The differences in yield between plots receiving different insecticidal treatments were due to differences in soil fertility or resistance to drought.

In experiment 6, the 20 per cent chlorinated camphene was slightly better than the 10 per cent dust and the 10 per cent dust was slightly better than calcium arsenate in terms of both bollworm control and yield.

In experiment 7, the chlorinated camphene-DDT dust gave slightly better bollworm control than the 20 per cent chlorinated camphene. The full effect of this control was not reflected in the yields because of excessive shedding of fruit in the treated plots owing to extremely hot, dry weather.

In experiment 8, the 20 per cent chlorinated camphene gave bollworm control approximately equal to that obtained from 10 per cent DDT. Both treatments gave fair gains in yield over the untreated check.

SUMMARY.—Several of the new insecticides were tested in small-plot and large-scale field experiments at Waco, Tex., during 1947 against light to moderately heavy infestations of the bollworm *Heliothis armigera* (Hbn.). The following dusts gave about equal control of the bollworm in these experiments: 20 per cent chlorinated camphene; a mixture containing 5 per cent of DDT and enough technical benzene hexachloride to bring the gamma isomer content to 3 per cent; and a dust containing 10 per cent of DDT. Each of these dusts gave better control than calcium arsenate. In some instances severe red spider mite infestations resulted following the use of chlorinated camphene in an inert diluent, but when at least 50 per cent of sulfur was included in the dust, there was no red spider mite build-up.—5-3-48.

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Effect of Dusting Schedules on the Yield of Cotton During 1947[1]

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The results of experiments conducted at the Texas Station during 1946 indicate that early season protection of cotton fruit from insect injury while producing early bolls, does not necessarily increase the total yield of cotton. Where adequate protection was given during the maximum fruiting period, the loss of 50 per cent of the squares from boll weevils, *Anthonomis grandis* Boh., during the first 30 days of the fruiting period did not reduce the yield. These results point to the probability that it may prove more profitable in Central Texas to dust cotton during the last 3 weeks of July and August—the period of severest injury by weevils and bollworms, *Heliothis armigera* (Hbn.), and at a time cotton is fruiting freely—than to make applications throughout the entire season.

Additional experiments were conducted during 1947 in an efiort to determine the minimum number of applications which could be made, in a schedule of applications, for the control of all cotton insects, and yet maintain a maximum yield. In general during this season, weather conditions were favorable for cotton production and unfavorable for insect development. However, in this area there was an extensive dry period, which limited the fruiting period of the cotton. The rainfall recorded during July and the first three weeks in August was less than normal, causing the cotton to mature rather early in August, thus allowing the first picking to be made in these experiments by August 13. In years when a normal rainfall is recorded in July, the possibilities are greater that the fruit lost early in the season from insect injury may be replaced during July and early August, provided adequate protection from the ravages of the weevil and bollworm is maintained.

Experiments herein reported were located in the Brazos River bottoms near College Station with the purpose of comparing early and late dusting schedules. The experiments were conducted in a similar manner using different materials on acre-sized plats. The three schedules compared in these tests were: (1) early dusting to control thrips followed by complete flea hopper, *Psallus seriatus* (Reut.), boll weevil and bollworm control; (2) dusting for standard cotton flea hopper, weevil and bollworm control and (3) late dusting for weevil and bollworm control. The infestation records were made in the usual manner at three points in each plat throughout the season.

Results.—In experiment 1, as shown in table 1, little plant injury developed although the thrips population was comparatively high. The percentages of "thrips injured" plants were: A-17.6, B-12.3, C-18.6, D-19.0. The applications of 5 per cent DDT-sulphur mixture failed to prevent thrips increases on the young cotton plants.

The early applications for thrips control and the pre-square applications of calcium arsenate-sulphur made on plat B, did not affect the weevil square infestation nor did it increase the yield. In fact, the yields were slightly lower on those plats dusted while the cotton was in the 4 to 8-leaf stage. It will be noted in table 1 that the average weevil infestation during the period, June 11 to July 5, was 40 per cent and the average flea hopper population during the period, June 5 to July 5, was 33 hoppers per 100 plants and reached a peak of 59 before the first dust application was made on plat D. The three applications of calcium arsenate-sulphur mixture applied to plat C, reduced the weevil and flea hopper infestations, and increased the yield, about 16 per cent over plat D. The weather being unfavorable for cotton fruiting during early August prevented the plants from replacing the fruit destroyed by insects in June. Calcium arsenate is a slow-acting poison, requiring at least 2 weeks to reduce the weevil infestation to below the danger point. This resulted in the lower yield on plat D. The results of similar tests (1947) indicate that even calcium arsenate applied late in the season will, under favorable fruiting conditions, yield as

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much cotton as the land is capable of producing.

In this experiment using calcium arsenate throughout the season, two applications of an aphicide, 3 per cent nicotine dust, were necessary to prevent injury from this pest. Nicotine sulphate was mixed with calcium arsenate and applied on July 20, and on August 5 nicotine sulphate mixed with lime was used. Both applications proved effective in reducing the aphid populations.

In experiment 2, as shown in table 2 the thrips population was also comparatively high and again a low percentage of "thrips injured" plants was recorded. The benzene hexachloride-DDT-sulphur mixture containing 3 per cent gamma isomer, 5 per cent DDT and approximately 40 per cent sulphur, used throughout the season on all plats as indicated in table 2, reduced the thrips population after each application. However, this mixture did not have a residual action. The early applications made for thrips and pre-square weevil control did not affect the weevil infestation nor increase the yield. As in experiment 1, the yields were lower on the plat dusted, when the cotton was in the 4 to 8-leaf stage. The average weevil infestation from June 10 to July 7, was 27 per cent and the average flea hopper population from June 5 to July 1, was 25 hoppers per 100 plants and reached a peak of 55 before the first dust application was made on plat D. The 4 applications made on plat C prior to the first application on plat D, reduced the flea hopper population and weevil infestation, but failed to increase the yield significantly. The benzene hexachloride-DDT mixture reduced the weevil infestation in a minimum length of time, thus allowing more time for the cotton to replace the fruit destroyed by insects earlier in the season. This mixture adequately protected the fruit from bollworm injury late in July. In this experiment, in which an effective, quick-acting insecticidal mixture was used, the yield on the plat receiving 6 late applications was approximately as high as the yield on plats receiving 8 and 11 applications. These 6 applications gave an increase of 696 pounds of seed cotton per acre, over the untreated plat.

Table 1.—Thrips population, flea hopper population, punctured squares, injured bolls, dates dust applications and yield on plats in experiment 1, College Station, Texas.

A—CHECK[1]				B—CALCIUM ARSENATE[1]				C—CALCIUM ARSENATE[1]				D—CALCIUM ARSENATE[1]			
	Thrips per Plant	Flea Hoppers per 100 Terminals	Sqs. Pct.		Thrips per Plant	Flea Hoppers per 100 Terminals	Sqs. Pct.		Thrips per Plant	Flea Hoppers per 100 Terminals	Sqs. Pct.		Thrips per Plant	Flea Hoppers 100 per Terminals	Sqs. Pct.
Date	*Number*	*Number*	*Per Cent*	*Date*	*Number*	*Number*	*Per Cent*	*Date*	*Number*	*Number*	*Per Cent*	*Date*	*Number*	*Number*	*Per Cent*
4/24	.03			4/18[2]	.07				.07				.03		
4/28	.51			4/29[2]	.68				.90				.37		
5/5	3.67			5/13[2]	1.40				4.03				5.00		
5/11	7.10				11.37				11.07				5.10		
5/26	15.86				6.10				13.93				13.16		
6/5		7.3		6/9[3]		15.7				42.3				47.3	
6/7		17.3		6/14[3]		21.0				29.3				22.3	
6/11		49.7	31.7	6/19		16.6	29.0	6/19[3]		52.7	21.0			58.7	25.0
6/13		26.7	16.3	6/21		8.3	18.7	6/21[3]		23.0	30.3			27.0	45.0
6/18		30.7	19.7	6/24		6.0	11.7	6/24[3]		37.3	40.3			33.0	29.3
6/23		34.0	19.3			13.4	5.7			8.0	14.7			41.6	15.3
6/27		20.4	56.0			3.0	10.0			10.0	15.7			24.7	63.0
6/30		28.3	57.0	7/1		4.4	41.3	7/1		7.0	25.7			31.0	52.0
7/5		17.7	64.7	7/5		1.0	48.3	7/5		.7	18.3	7/5		13.0	64.0
7/10			53.3	7/10			11.3	7/10			7.7	7/10			35.7
7/14			44.0				2.7				7.3	7/15			31.0
7/21			70.0	7/20			53.7	7/20			51.3	7/20			18.7
7/25			61.7	7/26			45.0	7/26			45.0	7/26			24.3
7/30			58.0	7/28				7/28			7.7	7/28			4.7
Ave.	5.43	29.6	46.0		3.92	7.5	24.8		6.00		21.5		32.7	4.73	22.9

[1] Seed cotton per acre: A-547, B-1502, C-1538, D-1300.
[2] 5% DDT-sulphur mixture.
[3] Calcium arsenate-sulphur (1–2).
Average per cent bollworm injured bolls: A-7.5, B-9.3, C-4.5, D-9.0.

SUMMARY.—The 5 per cent DDT-sulphur mixture used in experiment 1 did not prevent thrips increases, nor did the benzene hexachloride-DDT-sulphur mixture used in experiment 2. Therefore, the applications made for thrips control did not increase the yield. Apparently, the yield was reduced slightly on the plats

Table 2.—Thrips population, flea hopper population, punctured squares, injured bolls, dates dust application and yield on plats in experiment 2, College Station, Texas.

A—CHECK[1]				B—BENZENE HEXACHLORIDE-DDT-SULPHUR[1]				C—BENZENE HEXACHLORIDE-DDT-SULPHUR				D—BENZENE HEXACHLORIDE-DDT-SULPHUR[1]			
	Thrips per Plant	Flea Hoppers per 100 Terminals	Sqs. Pct.	Dusted	Thrips per Plant	Flea Hoppers per 100 Terminals	Sqs. Pct.	Dusted	Thrips per Plant	Flea Hoppers per 100 Terminals	Sqs. Pct.	Dusted	Thrips per Plant	Flea Hoppers per 100 Terminals	Sqs. Pct.
Date	*Number*	*Number*	*Per Cent*	*Date*	*Number*	*Number*	*Per Cent*	*Date*	*Number*	*Number*	*Per Cent*	*Date*	*Number*	*Number*	*Per Cent*
4/24	.05			4/18	.00				.07				.07		
4/28	1.49			4/29	.45				1.80				1.62		
5/5	8.76				.30				5.90				4.38		
5/11	8.36			5/13	4.47				8.58				9.98		
5/26	11.66				11.40				10.93				8.70		
6/3		7.4				6.7				25.7				15.7	
6/7		9.7				12.7				18.0				12.6	
6/10		39.3	34.7	6/11		35.0	40.7	6/11		46.0	21.7			55.0	24.7
6/16		39.0	19.3	6/17		3.7	15.3	6/17		10.7	6.3			43.6	27.3
6/20		26.6	17.7	6/23		.0	4.0	6/23		.7	3.0			20.0	10.7
6/27		8.3	29.6			.0	4.0			.3	5.7			3.0	18.7
7/1		39.2	49.7	7/2		1.0	32.0	7/2		5.7	36.0			31.7	44.3
7/7			48.3	7/7			19.7	7/7			39.3	7/7			36.3
7/11			25.3				5.0				9.7	7/12			34.3
7/16			42.7	7/17			8.7	7/17			6.0	7/17			11.7
7/21			40.3	7/22			11.3	7/22			7.3	7/22			1.0
7/26			60.7	7/27			24.7	7/27			17.0	7/27			6.0
7/31			50.7									8/14			9.3
AVE.	6.06	28.3	37.1		3.32	1.2	13.9		5.46	4.4	14.5		49.5	24.6	21.5

[1] Seed Cotton per acre: A-721; B-1488; C-1517; D-1417.
Average per cent bollworm injured bolls: A-26.7; B-3; C-2; D-1.7.

which received dust treatments for thrips control at the time cotton was in the 4 to 8-leaf stage of growth. If cotton is forced to set fruit early, this tends to retard vegetative growth and apparently reduces the yield.

The flea hopper population was reduced with the calcium arsenate-sulphur mixture used in experiment 1, but not as effectively as in experiment 2, in which the benzene hexachloride-DDT-sulphur mixture was used. The control of the flea hopper and weevil during June contributed to increased yields in experiment 1, due to the unfavorable weather conditions in early August for fruit production, and the ineffectiveness of calcium arsenate to control weevils in a short period of time. The benzene hexachloride-DDT-sulphur mixture acted quickly, thus allowing the cotton to refruit in a minimum period of time. In spite of no hopper control and unfavorable weather conditions for fruit production, the plat treated late in the season, requiring 6 applications, yielded practically as much cotton as the plats dusted 8 and 11 times. These results indicate that it is more profitable to dust cotton during the last 3 weeks of July and August with a quick-acting, effective insecticidal mixture, at a time when the weevils and bollworms are most injurious, than to try to protect the fruit during the entire season.—12-20-47.

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Adalia bipunctata IN BUILDINGS IN WASHINGTON

Hibernating individuals of *Adalia bipunctata* L. frequently occur in ones and twos in houses in Seattle, Washington, in the winter. In the winter of 1948 and for several winters previous in many of the homes and other buildings in the coal mining community of Black Diamond, Washington, a veritable plague of beetles of this species developed. On March 4, 1948, we were informed that it was more difficult to find buildings without beetles than with them in that community. Three homes and one store were visited and numbers of the beetles were observed. Large numbers were seen in a store window and in the crevices of a porch. One woman reported that upon the removal of a coal shed from her yard in the spring of 1947 a mass of beetles 6 to 8 inches deep and over a yard square was revealed. This same person reported that the beetles would gather in great numbers on the outer wall of the building, perhaps attracted by the warmth, and enter the building through any available crevices, and this seemed in general to be the source of the beetles rather than hibernating masses within the buildings. The case of a near-by miner's mess hall was reported in which eating was rendered unpleasant because of the numbers of the beetles. It is interesting that this, almost the only introduced Coccinellid in the Pacific Northwest, should be the only species so far observed to invade buildings. It would seem that the same factors may be involved in both cases.

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Inorganic Salts as Repellents for Package-Penetrating Insects

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The penetration of food packages by insect pests is a long-standing problem. Essig *et al.* (1944) reviewed the literature on penetration by insects and described studies on its prevention. They reported that the impregnation of packaging materials by certain repellent organic chemicals seemed to afford a possible solution to the problem.

From the results of research on the sense of taste of the Cecropia moth caterpillar, the American cockroach, and female horseflies (Frings 1945, 1946; Frings & O'Neal, 1946), it is obvious that ammonium and potassium salts are very repellent to these insects. Since many of these compounds are easily obtained, are non-toxic to man, and have for this purpose the advantage over organics of being non-volatile and non-odorous, they were tested as impregnants for packaging materials. Considerable testing was done with ammonium chloride and ammonium nitrate, and the data from these tests seem worthy of report. Though no clear-cut practical suggestions come from them, they indicate a new approach to the study of repellency and show the difficulties encountered in research in this field.

MATERIALS AND METHODS.—Heavy bond paper and cardboard were impregnated with ammonium chloride, NH_4Cl, or ammonium nitrate, NH_4NO_3, by immersion in saturated aqueous solutions of the salts for 2 to 4 hours, followed by draining and drying. Those treated with NH_4NO_3 have a beautiful coating of crystals when dry, but the absorption of water from the air by the salt causes the paper and cardboard gradually to become moist and soft, especially during damp weather. In general, this property alone renders paper and cardboard thus treated more vulnerable to insect attack and not too favorable for packaging. It is possible, however, to dry out these materials and keep them dry by coating with paraffin or wax.

Paper and cardboard treated with NH_4Cl, on the other hand, look much like untreated materials, and, since NH_4Cl is much less deliquescent than NH_4NO_3, they usually retain their stiffness and make as good packaging materials as untreated samples. These too can easily be coated with paraffin or wax if desired. The coating would be necessary if the materials were to be used for packaging foods which might pick up the distasteful salt, or if the packages were to be stored in an area of high humidity.

Essig *et al.* (1944) devised two ways of testing the resistance of packaging materials to insect penetration. In one, the insect is confined with a standard packet containing food until penetration or death occurs. In the other, the insect is confined in an arena made by inverting the replaceable section of a two piece self-sealing lid, on a disk of the material to be tested, over the mouth of a pint fruit jar, the whole being held in place by the separate ring-type screw-cap. As a modification of the second method, the arena floor was made of two semicircles of material, one treated, the other untreated. Food in the fruit jar was used in some cases as an attractant, but its role was questionable.

Both these methods of testing were used in this study. Three animals were used as penetrants: the American cockroach, *Periplaneta americana*, the mealworm, *Tenebrio molitor*, and the larva of the cadelle, *Tenebroides mauritanicus*. Laboratory temperatures and relative humidity were uncontrolled; temperatures ranged from 22° to 27° C., relative humidity was unknown. As noted by Essig *et al.* (1944), the relative humidity is an important factor in penetration, and the lack of control of this was undoubtedly responsible for the absence of penetration of the untreated packages in some of these tests.

EXPERIMENTS WITH ROACHES.—Roaches were placed in battery-jars with paper toweling floors and were supplied only with water and packets made by enclosing graham crackers in a single layer of bond paper, either treated or untreated.

In about two weeks all the untreated packets were penetrated by the roaches with which they were placed. None of the treated packets, however, was penetrated, all the roaches starving to death

without penetrating to food. One roach covered an egg-case with frass made from the edge of a treated packet, and a few nibbled the treated packets slightly, but they did not continue to molest them.

Tests were made with roaches starved for 2 weeks and then offered matched packets, untreated and treated, containing graham crackers. The roaches attacked the untreated packets almost immediately and penetrated them within a matter of hours. When the untreated packets were removed, however, the roaches starved to death rather than eat through the treated packets. These roaches were often observed examining the treated packets, but they refused to eat through whenever their mouth-parts touched the salt.

EXPERIMENTS WITH MEALWORMS.—Attempts made to test penetration of packets by meal-worms were unsuccessful because of the failure of these animals to penetrate even untreated packets.

The first two sets of arena tests were made with treated and untreated bond paper as covers, 5 larvae in each arena, and with either a median half inch fold or a wedge-shaped fold extending from the center to one edge. In both cases, the untreated disks were readily penetrated, requiring about 1 month if the larvae were fed before testing and about 1 week if they were starved for 2 weeks before testing. The NH_4NO_3 paper was penetrated sooner than the untreated, suggesting that, since the larvae were forced to lie on it, it was irritating. As noted above, NH_4NO_3 proved to be quite hygroscopic, and the paper became rather moist. NH_4Cl treated paper was penetrated in only 30 per cent of the trials, showing some repellency. All the penetrations through NH_4Cl treated paper were in the second set of tests, when the weather was very damp and rainy, and this paper also tended to become somewhat moist.

The first method tested to obviate the possible irritating effect of the salts was to place a piece of treated paper under the untreated, make a median fold, and use this for the arena, using 5 larvae in each. In eleven tests, only 4 penetrations occurred, all through the NH_4NO_3 treated papers, and in these the untreated paper had become damp from the treated paper below. Mostly there was extensive nibbling on the untreated paper which was stopped by the treated layer.

The second method used to obviate the possible irritating effect was similar to that used by Essig *et al.* (1944). Semi-circles of treated and untreated paper were folded together 3 times at the junction and used as an arena, thus affording half treated and half untreated surfaces. This proved unsatisfactory, because in many cases, the fold prevented the larvae from moving freely from one part to the other. In all, 46 larvae, in groups of 2, starved for 10 weeks before the tests, were used in 13 tests with NH_4NO_3 and 10 tests with NH_4Cl. The results indicated clearly that the salts were repellent. There were eleven penetrations on the untreated, and only 5 on the treated, even though in some cases the larvae were forced by the fold to remain on the treated paper. There were no penetrations of treated papers where the larvae could move to the untreated side.

The method found most satisfactory was a modification of the halved arena method outlined above. In this, identical semi-circles of treated and untreated cardboard were fastened together with tape and used as the arena. The larvae could then crawl readily from one of the semi-circles to the other. All the larvae nibbled the tape rather extensively, but none managed to break the bond, and thus penetrate. With NH_4NO_3, the hydroscopic properties caused the material to diffuse gradually into the untreated cardboard. In these, 40 per cent penetrated the untreated and none the treated, while 60 per cent showed nibbling, usually extensive, on the untreated and 30 per cent showed nibbling, in only one case extensive, on the treated. With NH_4Cl, diffusion did not occur. This experiment continued 3 months, and at the end of that time 30 per cent had nibbled on the untreated and none on the treated; there were no penetrations. The fact that irritation by the moist NH_4NO_3 was the cause of the penetrations in the previous tests is thus proved.

EXPERIMENTS WITH CADELLES.—Packets made of three thicknesses of paper or one thickness of cardboard containing middlings and flour, either paraffin-coated or plain, treated or untreated, were exposed to cadelle larvae in 56 tests. It was found that paper was more readily penetrated when paraffin coated. The treated paper packets did not seem to re-

pel the cadelles (30 per cent penetration), though the penetrations were few even with untreated packets (28 per cent, and thus the results are not clear-cut. Penetrations of all packets tended to be at the closures and many of them were without actual boring of the larvae through the materials. This emphasizes the importance of the point made by Essig *et al.* (1944). Linsley (1944), and Cotton (1944), that correct sealing of packages is perhaps the most important point of all in the prevention of penetration. Only one larva, in 46 tests, penetrated a cardboard packet, this one untreated. Thus the lack of penetration of treated cardboard packets by the larvae indicated nothing significant. The larvae were allowed 4 months for penetration, and, in view of the much longer times used by Essig *et al.* (1944), it may be that too short a time was allowed in these tests, though many of the larvae, being without food, had died by the end of the test period.

Arena tests with cadelles were strikingly positive, however, With untreated paper with a single median fold 90 per cent penetration occurred; with NH_4NO_3 treated paper no penetrations; with NH_4Cl treated paper 20 per cent penetrations. Those that penetrated the NH_4Cl paper, when tested with double thickness of treated paper, died without penetrating. Cardboard arenas with treated and untreated semi-circles proved unsatisfactory, because, though almost all the nibbling was on the untreated side, there were no penetrations.

DISCUSSION.—A few statements concerning methods of testing the repellency of chemicals used on packaging materials can be made:

(1) The arena method of testing, particularly using semi-circles of treated and untreated materials, offers a simple and relatively rapid method of testing, provided the impregnating material does not have a toxic vapor.

(2) The method utilizing matched packets of treated and untreated materials containing food gives results which can be most nearly interpreted in practical terms, but some method of securing uniform and rapid penetration of treated packets is necessary. The latter is particularly important if compounds are to be compared as to repellency, with a view to studying the effects of chemical structure on repellency or on antagonistic and synergistic effects.

(3) The case of the roach which made frass for covering the egg-case from a treated packet and still did not penetrate for food emphasizes the necessity for some equalization of drives in these tests. It is obvious that the drive which induces an insect to eat its way out of captivity, as in the arena tests, need not be of the same strength as that which induces it to eat through to food. Thus the final judgment on a repellent for packages will probably await critical tests under natural conditions.

(4) Experiments such as those of Sweetman & Bourne (1944) with paper laminated with asphalt, test only for attractiveness and not for repellency. Since no controls of untreated paper were used there was no incentive for the insects to eat the paper unless it, itself, was attractive, and food was available in most cases during the tests. Their times also were too short (7 to 11 days for roaches, for instance) for definite results.

Three points concerning the materials herein discussed and the problem in general can be made:

(1) The ammonium salts, particularly NH_4Cl, show promise as repellents for packaging materials. These have the advantage over organic compounds of being non-volatile and non-odorous, and it is possible to keep them from dissolving out of the packages or getting into the foods in the packages by wax-coating. Further tests under practical conditions seem justified.

(2) The need for further studies on the mechanism of stimulation of insects by chemicals, such as those of Frings (1945, 1946), Frings & O'Neal (1946), Chadwick & Dethier (1947), and Dethier & Chadwick (1947), is clear. These studies give us the opportunity to predict that certain compounds should be repellent without the usual trial and error. Studies, for instance, of the basic physiology of taste and smell of mosquitoes, flies, roaches, and other insects may indeed lead to the production of "custom-built" repellents for these forms.

(3) The results reported herein, as well as many other observations made during the course of this work, emphasize the importance of proper sealing and construction of packages, as Essig *et al.*

(1944), Linsley (1944), and Cotton (1944) have previously noted. No packaging material, no matter how inherently repellent or how well impregnated with repellents, can be successful in keeping insects out of food, if the package is not tightly sealed and does not have as smooth a surface as possible.

SUMMARY.—NH_4Cl and NH_4NO_3 were tested as repellent impregnating substances for packages, using the American roach, the meal-worm, and the cadelle as the penetrating insects. Both salts seem to have promise for this purpose, NH_4Cl being superior. Proper construction and sealing of packages, however, is probably the most important factor in excluding insect pests from packaged foods.

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Some Insecticidal Properties of Fluorine Analogues of DDT[1]

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One of the most interesting analogues of DDT to attain commercial importance as an insecticide is its fluorine analogue 2,2-bis-(*p*-fluorophenyl)-1,1,1-trichloroethane, more commonly known as DFDT, fluoro-DDT, or fluorogessarol.[4] According to Kilgore (1945), this material was extensively used in Germany as an all-purpose insecticide during the war years, and was manufactured at the rate of about 40 tons per month in 1944. Crude DFDT was compounded as an insecticide concentrate which consisted of 60 per cent crude DFDT, 20 per cent high-boiling petroleum oil, and 20 per cent emulsifier. It is stated that this material was preferred over DDT as a household insecticide and as a clothing impregnant.

Because of this extensive use of DFDT and the lack of published data on the insecticidal properties of the material it was considered of importance to evaluate some of its characteristics, and to study the insect toxicology of this and other fluorinated and chlorinated compounds related to DDT.

CHEMICAL PROPERTIES OF DFDT.—The synthesis and chemical properties of DFDT have been described by Martin & Wain (1944), Kirkwood & Dacey (1946), Müller (1946), and in greater detail by Bradlow & VanderWerf (1947).

Condensation of one mole chloral with 2 moles of fluorobenzene in the presence of sulfuric acid gives a crude product containing as little as 1 per cent *o-p'*-isomer, in yields up to 80 per cent. The crude material often remains liquid and can be formulated readily as a dispersible concentrate, as in *Gix*. Technical grades of

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[4] Hereafter referred to as DFDT in this paper to avoid reader confusion.

DFDT containing as high as 90 per cent *para-para'* isomer are semisolids, whereas the purified *p-p'*-DFDT crystallizes from alcohol as white needles (m.p. 44° to 45° C.). The pure compounds has a very pleasing odor of ripe apple. It has a boiling point of 177° to 178° C. at 9 mm. mercury, and thus has a vapor pressure. about 15 times that of *p-p'*-DDT (interpolated vapor pressure about 0.5 mm. mercury at 178° C., Balson 1947). In the presence of dilute alcoholic alkali, *p-p'*-DFDT liberates 1.0 mole hydrogen chloride per mole of compound to form 2,2-bis-(*p*-fluorophenyl)-1,1-dichloroethylene (m.p. 45° to 46° C.).

One of the most interesting properties of DFDT is its extraordinary solubility in organic solvents. Table 1 presents the results of solubility determinations of purified DFDT (m.p. 40° to 41° C.) in several solvents of importance in insecticidal formulations, at 27° C. Comparable values for purified DDT are presented from Jones *et al.* (1945). It is noteworthy that DFDT is more soluble in mineral oil and kerosene than DDT is in aromatic solvents such as xylene and polymethylnaphthalenes. Thus for insecticidal formulations of DFDT there is no need for auxiliary solvents.

Table 1.—Solubility of DFDT compared with that of DDT, in common solvents.

Solvent	Solubility at 27° C.	
	Para-para' DFDT[1]	*Para-para'* DDT[2]
	Grams.100 ml. Solvent	*Grams.100 ml. Solvent*
Mineral seal oil[3]	83	3.9[4]
Kerosene (white)	140	8–10
Dibutylphthalate	260	33
Polymethylnaphthalenes[4]	460	57
Carbon textrachloride	650	45
Xylene	670	53
o-Dichlorobenzene	700	59
Cyclohexanone	850	116

[1] Original data.
[2] Data from Jones *et al.* (1945), except as specified.
[3] A refined grade of mineral oil; boiling point range about 500° to 698° F.
[4] *Velsicol AR-60.*

DFDT is also highly soluble in certain emulsifying agents. For example, equal parts by weight of 90 per cent technical DFDT and certain oil-soluble emulsifiers form perfectly clear solutions, which, when emulsified with water, form stable emulsions of any desired DFDT concentration. The DFDT-emulsifier concentrate can also be added to mineral oils or kerosene in any proportion and then emulsified in water to form stable emulsions. A non-ionic emulsifier[5] was the most suitable of about twenty studied for this purpose, although an alkylated aryl polyether alcohol[6] was also fairly effective.

DFDT is readily formulated into conventional dusts and wettable powders by blending with suitable carriers. For example, a 50 per cent mixture, by weight, of 97 per cent technical DFDT with a clay[7] or diatomaceous earth,[8] produced by solvent impregnation with acetone or by grinding, was free-flowing, but an oily phase separated upon wetting. The incorporation of 1 per cent of a wetting agent such as those previously mentioned, however, produced a material which wet readily and behaved in a homogenous manner.

PHARMACOLOGY.—Limited data appear to indicate that DFDT is somewhat less toxic than DDT to warm-blooded animals. For example, von Oettingen & Sharpless (1946) found that, to the white rat, the oral median lethal dose of DFDT in olive oil was 900 mg. per kg. of body weight, as compared with 200 mg. per kg. for DDT. Like DDT, however, DFDT fed to rats has been shown to accumulate in the perirenal fat, whereas the related compound 2,2-bis-(*p*-fluorophenyl)1,1,1-trifluoroethane did not (Kirkwood & Phillips 1946). This appears to indicate that the property of accumulation in fatty tissue of DDT-type compounds is associated with the trichloromethyl group.

RELATION OF MOLECULAR STRUCTURE TO INSECTICIDAL ACTION OF CHLORINATED AND FLUORINATED COMPOUNDS RELATED TO DDT.—In connection with the problems of the relation of molecular structure to insecticidal action, data were obtained on the speed and quantity of insecticidal action of a series of pairs of compounds identical in structure except for the interchange of chlorine and fluorine atoms. The tests were made on residues of the purified materials deposited from standard acetone solutions. The residues were deposited on filter papers in petri dishes for the tests on *Drosophila melanogaster*

[5] *Atlox 1045a*, Atlas Powder Co.
[6] *Triton X-100*, Rohm & Haas Co.
[7] *Attaclay*, Attapulgus Clay Co.
[8] *Celite 209*, Johns-Manville Corp.

Table 2.—Comparison of toxicity and speed of toxic action of DDT, DFDT, and certain of their analogues to *Drosophila* and the greenhouse thrips.

Compound and Formula	Melting Point	*Drosophila*: Time Required for 50 Per Cent Knockdown (15 Micrograms Toxicant per Cm.[2] Filter Paper)	Greenhouse Thrips: Concentration of Toxicant	Greenhouse Thrips: Mortality in 24 Hours
	°C.	*Hours*	*Per Cent*	*Per Cent*
1. 2,2-Bis-(*p*-chlorophenyl)-1,1,1-trichloroethane (DDT) $(ClC_6H_4)_2HCCCl_3$	109	8	0.005	100
			0.0025	88
			0.001	46
			0.0005	25
2. 2,2-Bis-(*p*-fluorophenyl)-1,1,1-trichloroethane (DFDT) $(FC_6H_4)_2HCCCl_3$	44	1	0.01	100
			0.0075	60
			0.005	37
			0.0025	0
3. 2,2-Bis-(*p*-chlorophenyl)-1,1-dichloroethane (DDD) $(ClC_6H_4)_2HCCHCl_2$	110		0.1	100
			0.05	100
			0.025	96
			0.01	72
			0.0025	26
4. 2,2-Bis-(*p*-fluorophenyl)-1,1-dichloroethane (DFDD) $(FC_6H_4)_2HCCHCl_2$	77[1]	3.5	0.1	100
			0.05	94
			0.025	90
			0.01	57
5. 2,2-Bis-(*p*-chlorophenyl)-1,1,1-trifluoroethane $(ClC_6H_4)_2HCCF_3$	60–61	6	0.1	34
			0.05	28
6. 2,2-Bis-(*p*-fluorophenyl)-1,1,1-trifluoroethane $(FC_6H_4)_2HCCF_3$	79–80	5	0.1	52
			0.05	33
7. 2,2-Bis-(*p*-chlorophenyl)-1,1-dichloroethylene $(ClC_6H_4)_2C=CCl_2$	84–85	24	1.0	24
8. 2,2-Bis (*p* fluorophenyl)-1,1-dichloroethylene $FC_6H_4)_2C=CCl_2$	45–46	6	1.0	100
			0.1	0
9. 3,3-Bis-(*p*-chlorophenyl)-2,1 ,1-trichloropropene $(ClC_6H_4)_2HCCCl=CCl_2$	181–184[2]	24	1.0	0
10. 3,3-Bis-(*p*-fluorophenyl)-2,1,1-trichloropropene $(FC_6H_4)_2HCCCl=CCl_2$	149–150[2]	24	1.0	31
11. 4,4'-Dichlorobenzohydrol $(ClC_6H_4)_2HCOH$	92–93	24	1.0	10
12. 4,4'-Difluorobenzohydrol $(FC_6H_4)_2HCOH$	34–36	24	1.0	67
13. 4,4'-Dichlorobenzophenone $(ClC_6H_4)_2CO$	145–146	24	1.0	42
			0.1	0
14. 4,4'-Difluorobenzophenone $(FC_6H_4)_2CO$	106–107	24	0.1	17

[1] The writer is unable to explain the discrepancy between the melting point (77° C.) of this authentic sample, which was supplied by Dr. Paul Müller and described in his paper (1946), and that of the same compound as described by Bradlow and VanderWerf (1947), m.p. 44° to 45° C. Samples of both have been tested and the Müller compound appears to be slightly more toxic.
[2] Boiling point at 0.2 mm.

Meigen, and on mature Valencia oranges for the tests on the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché). The data obtained in these tests are shown in table 2.

The information indicates that the substition of fluorine atoms for chlorine atoms in the *para-para'* positions of the aromatic rings results in a more rapid insecticidal action wherever the aliphatic portion of the molecule is adequate for the production of an appreciably toxic compound, as for example where the aliphatic group is trichloroethane, dichloroethane, trifluoroethane, or dichloroethylene. This speeding up of the toxic action may be a reflection of the higher volatility of the fluoro-analogues, or it may be a more fundamental property of the bis-(*p*-fluorophenyl)-methylene linkage. As found by Kirkwood & Dacey (1946), the substitution of a trifluoromethyl group for a trichloromethyl group in the DDT or DFDT molecule results in a markedly decreased toxicity. It is interesting in this connection that fluoroform (HCF_3) has no appreciable anesthetic action (Henne 1937).

The substituted trichloroethanes and dichloroethanes were outstandingly toxic, as reported previously by Müller (1946); and in these pairs of compounds DDT appeared slightly more toxic than DFDT (of the trichloroethanes), and DDD than DFDD (of the dichloroethanes). In all the other pairs of compounds the fluoro-derivatives were slightly more toxic than the corresponding chloro-derivatives. It is believed that intrinsically the bis-(*p*-fluorophenyl)-methylene group is the more toxic of the two combinations, but that it also produces a more volatile molecule than the corresponding bis-(*p*-chlorophenyl)-methylene group; this consequently rapidly decreases the amount of toxic residue from applications at very low dosages, and results in a lower apparent toxicity for the more volatile materials.

Comparisons of Insecticidal Action

OF DDT, DFDT, AND RELATED MATERIALS.—Comparisons of the insecticidal action of DDT and DFDT on a few species of insects have been reported by Martin & Wain (1944), Proverbs & Morrison (1947), Prill *et al.* (1946), Deonier *et al.* (1946), Busvine (1946), Müller (1946), and Domenjoz (1946). In general, the toxicity of DFDT to insects was comparable to that of DDT, both being more toxic to some species and less toxic to others, the toxicity depending in part on formulations and methods of testing.

In order to further evaluate DFDT as an insecticide, a number of laboratory tests were made, comparing sprays, dusts, and residues of DFDT (m.p. 40° to 42° C.) with DDT (m.p. 108° to 109° C.).

Aonidiella aurantii (Mask.).—California red-scale crawlers were exposed to residues of DDT and DFDT by spraying grapefruit infested with adult scale (36 days old) with aqueous emulsions containing varying amounts of 20 per cent xylene solutions of the two materials. Blood-albumin spreader was used as the emulsifier at a concentration of 0.03 per cent. The fruit was held for 3 weeks after spraying to enable the crawlers to emerge and settle. The number of live second-instar scales per adult female was then determined on the treated fruit and compared with the number on untreated check fruit.

No mortality of adult scale was obtained with any of the treatments. Mortality of immature scale, however, was as follows:

Concentration (Cc. per Liter)	Per Cent Mortality with	
	DDT	DFDT
5	100	90
2	100	68
1	100	55
0.5	99	0

DDT is therefore much more effective than DFDT in preventing the settling of red-scale crawlers. This increased effectiveness of DDT is probably due to the greater volatility of the DFDT, which rapidly reduces the effective residual action of DFDT.

Blatella germanica (L.) and *Oncopeltus fasciatus* (Dall.)—The effectiveness of DDT and DFDT to the German cockroach and to the large milkweed bug was measured by placing the adult insects on crystalline deposits of 2.5 mg. of material per square centimeter of filter paper in open beakers. DFDT appeared to be much more effective than DDT against both insects, giving 100 per cent mortalities in 48 hours, whereas DDT in 96 hours produced no mortality of the roaches and only 60 per cent mortality of the milkweed bugs.

Listroderes obliquus Klug.—Adult vegetable weevils were placed on Malva leaves dusted with 5 per cent DDT and DFDT in pyrophyllite at 0.085 mg. of the compound per square centimeter of leaf area. The mortality in 96 hours was 100 per cent with DFDT and 70 per cent with DDT.

Drosophila melanogaster Meigen.—Tests were made on these flies by impregnating 9-cm. filter papers with 1 ml. of standard acetone solutions of DDT and DFDT. The papers were dried and rolled into shell vials. About 25 flies were introduced into each of the vials, which were then plugged with cotton soaked in 10 per cent sucrose solution. The average 24-hour mortality counts of 8 replicates at each dosage are presented in table 3.

Table 3.—Comparative toxicity of DDT and DFDT to adults of *Drosophila melanogaster*.

Concentration of Toxicant per Cm.² Filter Paper	Mortality in 24 Hours with—	
	DDT	DFDT
Microgram	*Per Cent*	*Per Cent*
0.16	78	63
0.08	52	36
0.04	35	23
0.016	24	0

Apantesis proxima G.-M.—Last-instar larvae of this arctiid caterpillar were allowed to feed on 10 per cent moist-bran baits of DDT and DFDT. One-tenth gram of poisoned bran was supplied to each larva, and this was completely consumed. Fresh wild mustard leaves were provided for the larve after the bran was eaten. After 96 hours, 65 per cent of the DDT-treated larvae were dead, with only a trace of leaf feeding; and 30 per cent of the DFDT-treated larvae were dead after slight feeding had taken place.

Phryganidia californica Pack.—Last-instar larvae of the California oakworm

were placed on live-oak leaves dusted with 5 per cent dusts of DDT and DFDT in pyrophyllite, at approximately 0.085 mg. of compound per square centimeter of leaf area. After 96 hours, 75 per cent of the DDT-poisoned larvae were dead, with no leaf feeding; and 55 per cent of the DFDT-poisoned larvae were dead, with a trace of feeding.

Tribolium confusum Duv.—Adult confused flour beetles were placed on treated filter papers in open petri dishes. Exposure to residues of 15 micrograms per square centimeter of filter paper resulted in the following mortalities in 120 hours: with DDT, 81 per cent; DFDT, 91 per cent; DDD, 2 per cent; DFDD, 2 per cent.

Cantharis consors (Lec.).—The following results were obtained with adult beetles in closed petri dishes on toxicant residues of 150 micrograms per square centimeter of filter paper: with DDT, 100 per cent knockdown in 24 hours; with DFDT, 100 per cent knockdown in 1.5 hours; with DDD, 80 per cent knockdown in 24 hours; and with DFDD, 100 per cent knockdown in 24 hours.

Lucilia sericata (Meig.).—Adult flies were placed on residues of 1000 micrograms per square centimeter of filter paper in cloth-covered beakers. DFDT gave 100 per cent knockdown in 2 hours; DDT, 100 per cent in 18 hours.

Apis mellifera L.—Adult honeybees were placed on residues of 1000 micrograms per square centimeter of filter paper in cloth-covered beakers. DFDT gave 100 per cent mortality in 5 hours; DDT, 100 per cent in 20 hours.

Pogonomyrmex barbatus (F. Smith).—Adult red harvester ants were placed on residues of 1000 micrograms per square centimeter of filter paper in open beakers. DFDT gave 100 per cent knockdown in 16 hours; DDT, 100 per cent in 48 hours.

Paratetranychus citri (McG.)—Adult citrus red mites were placed on residues of DDT and DFDT deposited on mature Valencia oranges by dipping them in standard acetone solutions. Neither DDT nor DFDT produced any mortality in 24 hours at concentrations of 1 per cent. (Compare with data in table 2.)

COMPARATIVE DURATION OF RESIDUAL ACTION OF DDT AND DFDT.—As stated previously, the vapor pressure of DFDT is considerably higher than that of DDT; DFDT should, accordingly, possess a correspondingly shorter residual action. This was studied by applying residual deposits of DDT and DFDT to Valencia oranges by dipping them into 0.1 per cent solutions of the materials, drying, and holding them at 27° C. Two oranges treated with each material were each infested with approximately 25 greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), on successive days, and 24-hour mortality counts were made.

The mortality on the DDT-treated fruit remained relatively constant over a 2 weeks' period, and was 95 per cent after 14 days; whereas that on the DFDT-treated fruit, although 100 per cent on fruit infested 30 minutes after treatment, had fallen to 32 per cent on surfaces 1 day old, and to 17 per cent after 4 days. This indicates that DFDT possesses a much shorter residual action than DDT.

CONCLUSIONS AND SUMMARY.—A study has been made of some of the insecticidal properties of 2,2-bis-(*p*-fluorophenyl)-1,1,1-trichloroethane (DFDT) and DDT, and of the comparative insecticidal actions of these and related fluorinated and chlorinated materials on several species of insects and one species of plant-feeding mite. The following conclusions are drawn from the data presented.

1. In a comparison of several pairs of compounds of the general DDT type, differing only in the substitution of chlorine and fluorine atoms, the presence of aromatic fluorine atoms in the *para-para'* position greatly increased the speed of toxic action, and in general appeared to produce the more toxic compounds, although this substitution also resulted in marked changes in melting points and vapor pressures, which affected the results.

2. The substitution of fluorine for chlorine in the aliphatic portion of the DDT-type molecule resulted in a marked decrease in toxicity, to the greenhouse thrips.

3. DDT and DFDT were considerably more toxic to the insects studied than DDD and DFDD, and these four were the only analogues which appeared to possess adequate insecticidal properties.

4. Crystalline DFDT was about 8 to 10 times as soluble, on a weight basis, as

DDT, in the series of organic solvents used in the insecticidal formulations tested.

5. DFDT was about equal to DDT in its initial toxicity to most of the 12 species of insects studied, but was more rapid in its toxic action than DDT.

DFDT deserves especial consideration as an insecticide because of its high solubility, and because of its low mammalian toxicity and high volatility, which should render residue problems resulting from application to edible products less acute than with some other insecticides.

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Book Review

A CATALOGUE OF INSECTICIDES AND FUNGICIDES. By Donald E. H. Frear, Volume I. Chemical Insecticides X+203 pages, 1947. The Chronica Botanica Company, Waltham, Mass. Price $6.50.

In this carefully compiled volume, the literature has been covered up to January, 1944. References are given to approximately 10,000 chemical compounds that have been tested as insecticides. These have been classified according to a new system devised by the author. In this system a code number for each compound is built up from the numbers assigned to each constituent group present. The constituent organic groups have been broken down into 16 divisions based upon the elements present and arranged in order of decreasing complexity.

Within each division the first numbers are assigned to the noncyclic combinations, followed by the heterocyclic structures containing the elements other than carbon characteristic of the division. The inorganic groups are divided into those acting primarily as positive ions (cations) and those acting as negative ions (anions) in water solution.

Compounds are listed by code number. The information given includes the name, formula, synonyms, organisms against which the compound has been tested, with results, and references, including patents.

The organic chemist will readily understand the coding system.

Practice will develop facility in assigning code numbers to given compounds, and thus locating these or their relatives in the catalogue. Because chemical relationships are revealed in the listing, the volume will have particular value for those who wish to investigate the use of various constituent groupings as insecticides. Because it collects in one place, the vast majority of published results on tested materials (without attempting complete coverage on the widely used insecticides), this volume should save the student a great deal of time ordinarily spent in literature searches and, by allowing the preparation of brief summaries of previous work, result in the elimination of much duplication in further studies.

The catalogue will be of great value to the serious student of chemical constitution as related to toxicity. In addition, will be useful as a general reference, for a complete alphabetical index to all compounds listed will be appended to Volume II.—H. N. WORTHLEY.

Body-Temperature Measurements of the California Red Scale

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In making studies on the effect of temperature on the biology of the California red scale, *Aonidiella aurantii* (Mask.), the author (Munger 1948) found it necessary to determine the body temperature of the scales in the field. When working on the red scale in Palestine, Bodenheimer (1934) measured a differential of 31.5° F. between the body temperature of a scale on a leaf in the sun and the air temperature, when the air temperature averaged 80.4° F. Turrell *et al.* (1943) at Highland, Calif. found that the temperature of the rind of Valencia orange in full sun rose as high as 23° F. above air temperature when the air temperature was 104° F. Bodenheimer did not report any host temperatures or solar radiation, and Turrell did not measure any scale temperatures.

With a view to determining what temperature the scale attains under California conditions, and to finding the relation between the temperatures of scale, host, and air and the solar radiation, nearly simulataneous measurements of scale and of host very close to the scale were made in the field in two localities, Redlands and Whittier, and records were made of air temperatures and, in most cases, solar radiation.

PROCEDURE AND APPARATUS.—A copper-constantan thermocouple made of wire 0.001 inch in diameter was used to measure the scale temperature. The thermocouples used to measure the temperature of the host (except the leaves, which required the fine-wire thermocouple) were made of wire 0.013 inch in diameter.[1] The junctions were made of solder (half tin and half lead) with rosin for flux. The thermocouples were calibrated in a water bath against a Bureau of Standards certified mercury thermometer. The pliability of the wire made it necessary to puncture the integument of the scale with a sharp needle before inserting the thermocouple. For convenience, all temperature measurements were made on the mature female. The mature female scale measures nearly 2 millimeters in diameter.

[1] No. 28 B. and S.

Solar radiation was measured during most of the observations by means of a Gorczynski pyrheliometer which was calibrated in gram-calories per square centimeter per minute.

RESULTS IN SHADE.—The relation between scale, host, and air temperatures in natural shade was first determined. Temperature measurements of scales living on lemon fruit and green wood were made near Whittier on September 23 and 30, and of scales living on gray wood near Redlands on October 2, all between 1 and 4 P.M. The results of these measurements are given in table 1.

Table 1.—Temperatures of host, scales, and air near Whittier, Calif., in natural shade on lemon tree. Each measurement is an average of 2 to 4 readings, requiring from 3 to 82 minutes.

HOST	HOST TEMPERATURE	SCALE TEMPERATURE	AIR TEMPERATURE
	Measurements at Whittier		
Fruit, Sample 1	86.5° F.	85.1° F.	89.6° F.
	86.0	84.9	89.0
	87.3	87.3	86.0
	86.9	87.3	86.7
Sample 2	92.3	92.5	90.0
	91.6	92.1	90.0
Green wood	91.0	91.6	90.0
	90.3	91.0	90.0
	90.3	91.5	90.7
	Measurements at Redlands		
Gray wood	84.4	84.2	81.0
	84.4	84.6	81.0
	84.2	84.4	81.0

There was a close relation between the scale and host temperatures, the greatest deviations being +1.2° and −1.4° F. There was no consistent difference in temperature between scales on lemon fruit and those on wood. The host temperatures agreed very closely with the air temperatures.

RESULTS IN SUN.—The body temperatures of 18 scales exposed to the sun, near Whittier, were measured between 10 10 A.M. and 4 P.M. September 15 to 30, 1941. The scales were mostly on lemon fruit, but a number on gray wood and on leaves of lemon also were measured. Table 2 shows these measurements.

Table 2.—Temperatures of host, scales, and air near Whittier, Calif., in full sun on lemon tree. Each measurement is an average of 1 to 6 readings, requiring from 1 to 23 minutes.

Host	Host Temperature	Scale Temperature	Air Temperature	Solar Radiation per Square Centimeter per Minute
				Gram-calories
Gray wood	84.4° F.	90.1° F.	74.5° F.	—
	100.4	102.9	88.0	—
Leaf	86.9	89.1	75.1	1.53
	102.8	101.7	88.0	—
	92.7	94.2	89.1	1.11
Fruit	92.4	95.0	79.1	1.39
	94.2	95.5	79.4	1.28
	93.8	90.2	81.9	1.22
	102.9	105.3	86.9	—
	96.7	97.2	90.0	1.24
	100.4	102.6	90.0	1.34
	100.9	103.3	96.8	1.10

Table 3.—Temperatures of host, scales, and air near Redlands, Calif., in full sun on lemon and orange trees. Each measurement is an average of 1 to 7 readings, requiring from 3 to 68 minutes.

Host	Host Temperature	Scale Temperature	Air Temperature	Solar Radiation per Square Centimeter per Minute
				Gram-calories
Lemon leaf	98.2° F.	101.8° F.	80.6° F.	1.57
	100.2	102.4	94.6	1.36
Lemon fruit	94.2	95.2	81.3	1.21
	103.1	105.2	84.0	1.45
	100.4	98.6	84.4	1.23
	101.6	102.0	87.8	1.51
	100.0	99.3	88.2	1.32
	104.7	105.0	89.3	1.42
	102.9	103.1	89.4	1.45
	103.9	103.4	89.8	1.48
	111.9	113.2	93.0	1.50
	101.8	106.7	93.0	1.39
	107.0	110.0	93.4	1.35
	100.3	103.6	93.8	1.29
	100.6	100.9	94.5	1.31
	104.5	105.3	95.4	1.35
	105.4	108.0	96.8	1.30
	107.2	108.8	98.6	1.42
	107.8	109.4	98.8	1.39
	107.6	110.0	99.3	1.37
	106.0	106.4	100.5	1.34
	110.4	112.2	101.1	1.35
	108.1	109.3	101.2	1.35
Naval orange fruit	112.3	113.4	104.4	0.92
	114.8	112.1	104.5	1.34
	109.4	109.9	105.6	1.37
	109.0	107.4	106.5	1.40

The air temperatures ranged from 74.5 to 96.8° F. The greatest deviation of the scale temperature from the air temperature was +18.4° F., when the air was 86.9° F. This scale was on lemon fruit, the temperature of which registered 2.4° F. lower than that of the scale. The temperatures of all the scales, including some not given in the table, averaged 12.2° F. higher than those of the air, but only 1.0° F. higher than those of the host material.

At Redlands scale-temperature measurements were made between 11 A.M. and 3 P.M., in October 1941, August and September 1942, and July 1943. The scales were mostly on lemon fruits, but a number on leaves and fruit of navel orange also were measured. The results of these measurements are shown in table 3.

The air temperature ranged from 80.6° to 106.5° F. The pyrheliometer readings ranged from 0.92 to 1.57 gram-calories per square centimeter per minute. Analysis of the data showed no correlation between solar radiation and air temperature or scale temperature. It is probable that the higher air temperatures were associated with mass air movement from the desert. There was a negative correlation between the air temperature and the deviation of the scale temperature from the air temperature. The deviation tended to be less at higher air temperatures.

The greatest deviation of the scale temperature from the air temperature was +21.2° F. when the air temperature was 84.0° F. This scale was on lemon fruit and was 2.1° F. warmer than the fruit.

SUMMARY.—Body-temperature measurements of the California red scale, *Aonidiella aurantii* (Mask.), were made under a variety of conditions. In natural shade there was close agreement between air, host, and scale temperatures. In the sun there was somewhat less agreement between scale and host temperatures, and both rose above the air temperature. The greatest deviation of the scale temperature from the air temperature was +21.2° F. when the air temperature was 84.0° F. Deviation of the scale temperature from the air temperature tended to be less at higher temperatures. There was no correlation between solar radiation and temperature of air or of *scales*.—2-27-48.

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Effect of Constant and Fluctuating Temperatures on the Rate of Development of California Red Scale

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The relative effect of constant and fluctuating temperatures on the rate of development of insects is a subject that has been extensively investigated. Most of these studies on controlled temperature may be grouped into two main classes, according to the manner of varying the temperatures:

(1) A fraction of the developmental period is spent continuously at one temperature, and the remainder at a different constant temperature. When both temperatures have been within a range favorable to complete development of the insect if continuously exposed to such temperature, the usual result has been either acceleration or retardation of the rate of development as compared with the rate at constant temperatures, depending on the order in which the two temperatures were imposed (Bliss 1926, Brown 1927, Harries 1944). When a part of the exposure has involved lower temperatures, results have varied with the species. Parker (1930) found a marked accelerative effect of the prolonged exposure of grasshopper eggs to temperatures of 0° and 8° C., but other investigators have found a retarding effect on other kinds of insects under similar conditions.

(2) The insects are exposed to two changes of temperature daily, the change from one to the other being abrupt. When the lower temperature has been near or below the lowest point at which the insects could be reared under constant exposure, and the exposure to high temperatures has been short (4 to 8 hours), a considerable acceleration of the rate of development over that found at constant temperatures has usually resulted (Parker 1930, Cook 1927, Peairs 1927, Harries 1934, and Huffaker 1944). Cook has shown that this acceleration rate in cutworms was correlated with an increased metabolic rate during the exposure to high temperature. When the low temperature used was nearer to the medial range on the developmental curve, or when the daily exposure to high temperatures was longer, the acceleration rate was less marked and was not found in all cases.

There has been little work with a continuously varying temperature such as occurs in nature. An exception is the work of Headlee (1940, 1941) on *Aëdes aegypti*. In his first series of experiments growth was more rapid at a constant temperature of 75° F. than at temperatures having a mean of 75° but varying from 60° to 90°. When the variable temperature ranged from 50° to 80°, the variable and constant temperatures had like effects. In the second series the variable temperature of 50° to 80° caused a faster rate of growth than a constant temperature at the mean of the variable range, while with a range of 60° to 90° little or no acceleration because of the variable temperature was observed.

In the course of an investigation of the comparative biology of strains of the California red scale, *Aonidiella aurantii* (Mask.) at Whittier, California, data were obtained on the rate of development at constant and continuously varying temperatures.

METHODS.—Temperatures in the constant-temperature cabinets were checked with a calibrated thermometer. Accuracy of control varied from $\pm 0.1°$ to $\pm 0.5°$ C. in the different cabinets. Fans provided continuous circulation of air and drew in a constant supply of fresh air through a hole in the wall of each cabinet behind the fan. Fluctuating temperatures were obtained with a variable temperature thermoregulator as described by Munger (1944). Scale temperatures and temperatures just beneath the surface of the lemons were measured by thermocouples.

Methods of rearing the scales were similar to that described by Yust & Munger (1943). Two strains of scales which differed in their resistance to hydrocyanic acid gas were used, but, since there was little or no difference in their response to temperature in these experiments, and equal numbers of both strains were started in all experiments, no further distinction between strains will be made in this

paper. All scales were on lemon fruits. Six lemons were infested with newly emerged crawlers for each temperature. During the first instar 120 scales were marked and numbered on each lemon, and individual records were kept. The development of the scales was observed until the males became distinguishable in the second instar, and until the females reproduced or died. During the molting period and again at the time that reproduction was starting, the lemons were removed

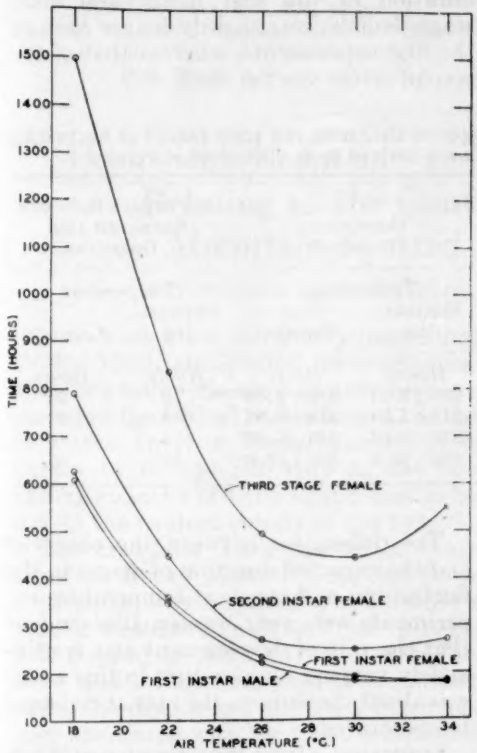

FIG. 1.—Duration of stages of California red scale at five constant temperatures.

singly for examination. About 7.5 minutes was required for each inspection. Inspections were made in rooms at temperatures which did not differ more than 4° C. from that of the cabinets with the exception of the 34° chamber. Scales were protected from heat from the microscope lamp by a filter containing copper sulfate solution.

Records on all the first and second instars except the ones in the 18° C. cabinet were made at 12-hour intervals, and observations were made every 24 hours on the third stage (covering the period from completion of the second molt to production of young) at all temperatures, and on all stages at 18°.

RESULTS.—*Constant Temperature.*—In order to provide the information necessary to compare fluctuating and constant temperatures, a series of experiments were made at constant temperatures of 18, 22, 26, 30, and 34° C. The time required to complete the different stages is shown in figure 1. The maximum rate of growth was reached at about 30° in the second instar and third stage, but the optimum temperature was higher in the first instar. The maximum number of scales which lived to produce young was 293 at 30° and the minimum number was 12 scales at 18°. However 162 scales completed the second instar at 18°. The data indicate that 18° is near the minimum constant temperature at which the female scales will complete their life cycles.

In order to test these results a similar experiment on the first and second instars was made at 26° C. on scales of the succeeding generation. In the first experiment the duration of the first instar of the male was 221 hours and of the female 233 hours, and that of the second instar of the female 270 hours. In the second experiment the corresponding durations were 234, 243, and 282 hours. Although the differences between the durations in the two experiments were slight, they were statistically significant ($P = 0.01$).

Fluctuating Versus Constant Temperature.—Since the experiments at constant temperature showed that the maximum velocity of development in some stages occurred at about 30° C. and that the minimum temperature at which the life cycle could be completed was near 18°, these two points were selected for the limits to be used in the fluctuating-temperature experiments. The temperature pattern used followed the equation $T = 24 + 6 \sin \theta$, where T = temperature and $\theta = 15$ times the number of hours starting from 11 A.M. Then 11 A.M. would be 0 hour, 12 M. 1 hour, etc., proceeding in a symmetrical curve with the minimum temperature at 5 A.M. and the maximum at 5 P.M. This pattern was repeated each day throughout the experiment. The average temperature for any interval can be obtained by integrating the foregoing equation.

The proportion of development expected to be completed in each hour was

calculated by reading from figure 1 the number of hours required at that temperature. The reciprocal of that figure gave the proportion of the total period completed in 1 hour at that temperature. Summation of these fractions showed that the expected time to complete the different stages corresponded to that found at the following constant temperatures:

	°C.
First instar, male	23.9
First instar, female	23.9
Second instar, female	23.6
Third stage, female	23.9

Since the two experiments at 26° C. constant temperature had shown a slight difference between scales of two generations, one lot of scales from the same group used in the fluctuating temperature was exposed to a constant temperature of 23.6° ± 0.05° simultaneously with the fluctuating temperature experiments. Inspections of the scales of the first and second instars were made at 5 A.M. and 5 P.M., and of the third stage females at 5 P.M. Therefore, each interval between observations had the same average temperature.

In the fluctuating-temperature cabinet the air temperature averaged 0.1° higher than planned, and the scale temperature 0.4° lower. In the constant-temperature cabinets the air temperature was the same as planned and the scale temperature 0.3° lower. Since the difference between the expected and observed temperature was 0.1° greater in the variable-temperature cabinet, a slight correction was made in the expected length of stages of scales reared under fluctuating temperature as read from figure 1. Results are given in table 1.

Comparison of the results at constant temperature with the earlier data shown in figure 1 gives further evidence of small differences in different generations. The duration of the first instar and third stage, female, was slightly longer than in the first experiments, whereas that of the second instar was the same.

Table 1.—Expected and observed duration of stages of California red scale reared at fluctuating and constant temperatures. The expected durations were derived from the curves of figure 1.

Stage	Sex	Expected Duration		Observed Duration		Difference Between Expected and Observed	
		Temperature Fluctuating	Constant	Temperature Fluctuating	Constant	Temperature Fluctuating	Constant
		Hours	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*
First instar	Male	279	285	298 ± 3.21	310 ± 3.86	19	25
First instar	Female	289	297	311 ± 5.04	318 ± 3.47	22	21
Second instar	Female	359	355	356 ± 4.05	355 ± 3.28	3	0
Third stage	Female	655	670	686 ± 13.6	696 ± 26.0	31	26

The differences between the observed and the expected duration of stages in the fluctuating and constant-temperature experiments were very similar. It is evident that the rate of development at a continuously varying temperature in this range was about the same as the rate at constant temperatures.

SUMMARY.—In an investigation at Whittier, California, data were obtained on the rate of development of the California red scale *Aonidiella aurantii* (Mask.) at constant and continuously varying temperatures. The constant temperatures ranged from 18° to 34° C., the fluctuating from 18° to 30°. The fluctuating temperatures did not produce any acceleration in the developmental rate.—12-21-47

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Ecological, Economic and Mechanical Considerations Relating to the Control of Ticks and Rocky Mountain Spotted Fever on Long Island

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New York State has a very interesting Rocky Mountain spotted fever problem. This tick borne disease has now been reported in the United States from 47 of the 48 states. In New York, however, it is known to be endemic only in the two eastern counties of Long Island, and to be rare in the western county of the two.

The first New York case to be diagnosed as Rocky Mountain spotted fever apparently was acquired on Gardiner's Island, where two cases occurred in 1912, and a third in 1913 (Anon. 1945; Van Dine 1913[1]). Beginning with these earliest cases, the disease in New York State has been associated with the tick *Dermacentor variabilis* Say, variously known as the American dog tick, eastern wood tick, and eastern spotted fever tick. No other cases were reported until 1924. Since 1924, cases and deaths have been reported in increasing numbers, and progressively from farther and farther west.[2] All of the earlier, and by far the larger number of reported cases apparently were acquired in Suffolk County. Later, a few cases have been reported from Nassau County (Anon. 1945)

CONTROL OF TICKS.—The earlier records were probably too incomplete to be geographically significant, but owing to the more general medical differentiation of the disease, records of the past 10 years give a more adequate picture of the distribution and local intensity of its endemicity. Between 1933 and 1946, 30 cases had been admitted to a single Long Island hospital (Southampton Hospital). From this series of 30 severe cases, nine of the patients died; a mortality of 30 per cent (Davis 1947). From 1912 through 1944, there had been 85 cases, all originating on Long Island, with 16 deaths (Anon. 1946); of these, only three cases and two deaths were reported from Nassau County. In the year 1944 alone, there were 17 cases and 4 deaths, all originating in Suffolk County. From 1912 through 1947, according to the latest available records (N. Y. State Dept. of Health), there had been reported from Long Island a total of 132 cases and 22 deaths.

Studies of the tick and the Rocky Mountain spotted fever problem on Long Island were begun in 1945 by Glasgow & Collins, of the New York State Science Service, at the request of officers of the Long Island State Park Commission. Through 1946 and 1947, these studies have been extended and continued jointly by personnel of the State Science Service, an agency of the University of the State

[1] Report of investigation made at request of W. D. Hunter.
[2] Possibly a result of increasing medical knowledge of the disease, rather than of any westward extension of the endemic area.

of New York (State Education Department) and personnel of the Division of Laboratories and Research, New York State Department of Health. The entomological and ecological aspects of the studies have been under the supervision of R. D. Glasgow, State Science Service, and the medical aspects under the supervision of John K. Miller, of the Division of Laboratories and Research.

The permanent residents of an area in which Rocky Mountain spotted fever is endemic can be given a high degree of protection against the disease by a course of two or three subcutaneous injections of anti-spotted fever vaccine administered at intervals of a week, preferably in early spring before the ticks become active (Shepard 1947). The resulting immunity can be maintained by a single "booster" injection of the vaccine each spring thereafter. This prophylactic vaccination is probably the most economical means of control for Rocky Mountain spotted fever in man, and is coming to be widely used by both permanent and summer residents of Long Island areas where spotted fever is endemic; but it has the disadvantage that the persistence of the disease in enzootic form will continue to be an undiminished health hazard for unvaccinated residents of, and visitors to such endemic areas.

The special nature of the Long Island problem arises predominantly from the coming and going of hundreds of thousands of non-immunized week-end picnickers, vacation campers, hikers, berry pickers, and other recreation seekers from New York City and elsewhere, and from the fact that a very considerable percentage of the reported cases of Rocky Mountain spotted fever have occurred among such transient urban visitors. Protection of these non-immunized visitors by vaccination appears to be highly impracticable, even if acceptable to them, and the only alternative to vaccination appears to be a substantial reduction of the tick-carrier population.

Fortunately, complete eradication of the ticks appears to be unnecessary, for it appears likely that, like malaria, Rocky Mountain spotted fever will vanish spontaneously if the tick vector population can be sufficiently reduced. It is a well established fact that malaria has disappeared spontaneously from formerly highly malarious areas, when the malaria-carrying mosquitoes had only been substantially reduced in numbers, and by no means exterminated (Russell *et al.* 1946). Indeed, there are many places in New York today where *Anopheles quadrimaculatus* is not rare, but where malaria has been unknown for many years. Evidently, for this disease, the mosquito population level in such places is below the critical level at which the malaria *Plasmodium* spontaneously becomes locally extinct.

The eastern spotted fever tick occurs sparingly throughout New York. In the two eastern counties of Long Island it becomes progressively more and more abundant, reaching extraordinary abundance on Montauk Peninsula.

Significantly, human cases of tick fever have occurred, or have been acquired in considerable numbers, only in areas where the eastern spotted fever tick is more than ordinarily abundant. Both frequency of spotted fever cases and deaths, and abundance of the tick vector diminish gradually from the Montauk Peninsula westward, until a point is reached beyond which no case of endemic spotted fever is known to have been locally acquired. This point would appear, like the reduced mosquito-to-man population ratio and the spontaneous disappearance of malaria, to mark a critical tick-to-human-to-wildlife population level below which the causative *Rickettsia* of Rocky Mountain spotted fever is no longer a human health hazard, and possibly, as with the *Plasmodium* of malaria, may likewise spontaneously become locally extinct.

If this hypothesis is sound, it would seem to be necessary only to reduce the tick population in any area to a point below that critical level, in order to bring about the complete and permanent eradication of Rocky Mountain spotted fever (disregarding, of course, its possible occasional and, by the hypothesis, temporary reintroduction). However, the hypothesis assuming the existence of such a critical tick population level is complicated as follows:

1. Mosquito-borne malaria appears to be exclusively an endemic disease, the causative *Plasmodium* depending for its survival in any area upon a continuing man-to-mosquito-to-man alternation of hosts. By operation of the law of chance, there is a critical mosquito-to-man popu-

lation-ratio, or a relative mosquito population level, at or above which, only, can there be opportunity for passage from mosquito-to-man-to-mosquito frequently enough to assure local survival of the pathogen. Below this critical mosquito population level, the *Plasmodium* pathogen, and with it the disease it causes (malaria) will spontaneously disappear, as it has been repeatedly observed to do (Russell *et al.* 1946).

2. But tick-borne Rocky Mountain spotted fever, by contrast, is basically an enzootic disease, with man only an occasional host among the many wild and domestic animal hosts of its tick vector. Moreover, the causative *Rickettsia* is so well adjusted physiologically to the tick vector, that not only does an infected tick remain a carrier throughout its individual life, as does a *Plasmodium*-infected mosquito, but unlike the malaria *Plasmodium*, the *Rickettsia* pathogen may be transmitted from an infected female tick by way of her eggs, apparently (and fortunately) to a portion only of the next, and succeeding generations of ticks (Miller 1947; Topping 1947).

While the resulting greater ecologic complexity of the tick and Rocky Mountain spotted fever problem demands a corresponding degree of caution in drawing parallel conclusions, the causative *Rickettsia* none the less depends for its survival in any area primarily upon a continuing mammal-to-tick-to-mammal alternation of hosts; and by operation of the law of chance, there should likewise be a critical tick population level below which the *Rickettsia* pathogen, and with it the Rocky Mountain spotted fever it causes should spontaneously disappear.

The transmission of the *Rickettsia* pathogen directly from generation to generation of the tick vector does introduce an ecologic complication, the practical significance of which can be established only by further study. The fact that the pathogen is transmitted from an infected female tick to only a portion of her progeny carries the suggestion that the tick species itself may be spontaneously self-cleansing. Certain erratic features in the "endemicity" of the disease suggest also that some ecologic factor or factors may contribute toward hastening any such local cleansing of the tick population (Glasgow 1947).

However that may be, the fact that, in the east to west gradually diminishing tick population, there is a point beyond which no indigenous case of tick fever has been reported, together with the substantially parallel and well authenticated experience with malaria, seems to justify the *working hypothesis* that a sufficient reduction of the tick population in areas of tick abundance should result not only in a correspondingly diminished direct health hazard, but also in suppression of the enzootic through the *Rickettsia* pathogen itself becoming locally extinct.

Accordingly, this hypothesis has been made the keynote for one of our major lines of study in the tick control problem. Under this hypothesis, we are working toward several objectives:

(1) To find usable criteria for recognizing the critical tick population level at or below which no cases of tick fever occur. These criteria are needed in order to set practical limits beyond which effort and expenditure for suppression of the tick vector need not go, and in order to gauge the tick fever hazard at various tick-to-wildlife-to-human population ratios. An exceptional opportunity for such ecological studies of the tick-wildlife-human spotted fever complex is provided by the western fadeout zone of the Long Island area where tick fever is endemic.

(2) To find practical means of drastically reducing the tick population, such as weak points in its life cycle, effective acaricides, and efficient mechanisms and methods for acaricide application. Because of the continued incidence of the disease, this has been our most immediate objective.

In 1945, large numbers of ticks were collected for use in screening tests to determine the relative promise of possible acaricides (Glasgow & Collins 1946). Some of the better ones were tested further in small field plats especially stocked with collected ticks. In these tests, DDT, and benzene hexachloride showed greatest promise.

This laboratory-scale testing work was continued through 1946 and 1947 with newly introduced insecticides. In addition, in 1946 and 1947 large scale practical field control experiments were carried out as rapidly and intensively as opportunity and available resources would permit.

With mosquito control well organized

in the area, well provided for, and already in active operation, including control of adult mosquitoes by spraying from the air, considerations of economy immediately suggested combining the tick and mosquito control programs where the two overlap. Although this overlap was rather considerable in the aggregate, it comprised only a fraction of the dangerous tick areas. Therefore, more direct practical and economical means of tick control also had to be worked out.

In 1946, three heavily tick-infested 160-acre (approximately half-mile square) plats were laid out and sprayed from the air with DDT; and one of the three plats was sprayed a second time. Upon an area of suitable vegetation near the center of each plat an open top, yard-square enclosure, with 18-inch walls of 18-mesh screen wire was set up, with the lower edge of the enclosure walls made tick proof by banking with sand. Before a plat was sprayed, the yard-square wire enclosure was stocked with 1000 collected ticks to provide an adequate numerical check on the effectiveness of the spray. A similar wire enclosure likewise stocked with 1000 ticks was provided at a safe distance as a check.

Smaller field plats stocked with collected ticks were treated experimentally with sprays and dusts applied with ground-operated equipment.

In 1947, another 160-acre plat was sprayed from the air with DDT, with the central open top wire enclosure and a remote check enclosure both heavily stocked with collected ticks; and, as in 1946, smaller field plats stocked with collected ticks were treated experimentally with sprays and dusts applied with ground operated equipment.

In the applications from the air, a 5 per cent solution of DDT in No. 2 fuel oil applied at an average rate of 2 gallons (0.8 pound of DDT) per acre gave adequate control of the ticks in a heavily infested area. The details of these and other tests will be given in another paper.

Control from the air, however, is recommended only where it may be advantageously combined with a program of spraying from the air for control of adult mosquitoes, or a similar operation, or where a large area inaccessible to ground-operated equipment is crossed by many tick infested paths or trails.

It has been observed by the authors, and also by other students of tick ecology, (Bishopp & Smith 1938; Gouck & Smith 1947; Smith & Gouck 1944a, b; 1945; Smith *et al.* 1946) that the eastern spotted fever tick population of a given area tends to become very largely concentrated at the margins of highways, truck trails, pathways, and well marked animal trails. This tendency to concentration is so pronounced that it was estimated for some heavily tick infested areas that as much as 90 per cent of the tick population was concentrated in less than 1 per cent of the area. This 1 per cent was along paths and roadsides, and therefore included the most accessible portions of the area.

Situations have often been observed where the ticks assembled within a few inches of a trail margin averaged more than 10 ticks per lineal foot; yet in collecting on a line parallel with the trail, but only 3 feet away, few ticks could be found.

This highly accessible concentration of the tick population, and the exposed position of the ticks while clinging to the grass awaiting the passing of a possible host animal, greatly simplifies the mechanics of tick control. Sprays and dusts of DDT and of benzene hexachloride applied to these narrow concentration zones have given remarkably complete destruction of the assembled ticks.

With acaricide sprays applied broadcast from the air, we must take seriously into account any possible effect on wildlife. With sprays or dusts applied only to the narrow zones of tick concentration, however, economy of materials is the only factor which need limit the amount of acaricide applied per unit area; for even if so small a percentage of the total area were completely denuded of insects and other wildlife, such small denuded areas would be quickly repopulated by sheer population pressure from adjacent untreated areas.

With DDT applied at the rate of 1 pound per acre, and with coverage of a strip 4 feet wide on each side of a highway or trail, the application would be at the rate of approximately 1 pound per mile. In our control experiments this has given adequate control, but even several times this amount applied to so small a fraction of the total area should have no conceivable effect on the general biologic balance.

With a benzene hexachloride dust con-

taining 1 per cent of the gamma isomer, an application equivalent to 1 pound of the gamma isomer per acre, or per mile of two 4-foot wide strips, has given almost complete destruction of the accumulated ticks.

Applied broadcast from the air, or applied with ground-operated equipment to narrow zones of tick concentration along roadsides and trails, or to small field plats specially stocked with collected ticks, DDT applied at the rate of 1 pound per acre, whether in the form of dusts, solutions, emulsions, or suspensions has given excellent control at a lower cost for materials than any other acaricide material thus far tested in the course of these studies. Benzene hexachloride applied at the rate of 1 pound of the gamma isomer per acre was probably equally good or a little better but the cost was greater.

In applications of these kinds it is frequently difficult to adhere to an exactly specified dosage per acre. It would be safer to describe the effective application as between 1 and 2 pounds per acre, although under the test conditions, the 1 pound per acre dosage was satisfactory.

For the mechanics of applying the two acaricides named in the same manner, the cost should be substantially the same; but the greatest economy and efficiency will require improved equipment specially designed for tick control work.

Much work remains still to be done. Included among the points on which further knowledge must be obtained are the following:

1. The ecological factors which govern the critical tick population level at which cases of tick fever no longer occur, as a measure for adequate tick control in areas of tick fever endemicity.

2. The factors which govern the local intensity of a tick fever enzootic in order to develop practical means of gauging such enzootic intensities.

3. Newer and possibly more effective acaricides, in the search for the most effectual and economical tick and spotted fever control procedures.

4. Refinements of equipment necessary to provide more effective and more economical application of proven acaricides.

Even at the present stage of the work, however, we can advise local pest control commissions that, as available funds permit, they may begin tick eradication work where spotted fever incidence is highest with full assurance that local tick populations may be very substantially reduced at moderate cost, with a corresponding reduction in the local tick fever hazard.—4-12-48.

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Determination of 4-6 Dinitro-o-Cresol on Bark Surfaces and Some of Its Applications[1,2]

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This is the second of two papers reporting the studies conducted at this station since 1944 on the toxicology of 4-6 dinitro-o-cresol as an aphid ovicide. It was of immediate concern in this work to learn if any correlation existed between the amount of toxicant used and the control efficiency obtained for different forms of the toxicant and against various species of aphids.

Aphid eggs occur on bark surfaces which vary greatly in character, some being hard and smooth, others waxy, while some are rough and broken, and other pubescent. In some cases the eggs are deposited on an exposed surface, but more commonly around the buds or in crevices of the bark. It would seem that the amount of toxicant deposited from a given spray mixture would depend not only on its concentration but also on the condition of the bark surface sprayed. That this is true is borne out by experiments to be described in this paper. It would also seem that the amount of toxicant deposited on the egg would not necessarily be the same as that deposited on the surrounding wood surface. While this question has not been entirely clarified in the present study, it was one of the considerations which led the authors to undertake the determination of the amount of actual toxicant in deposits on the surfaces sprayed.

Method.—A search of the literature revealed no published method for determining dinitro-o-cresol residues on plant surfaces. For making the final determination of the toxicant an adaptation of a method used in the laboratories of the Dow Chemical Company was employed.

A suitable number of sprayed twig sections are extracted with petroleum ether, boiling range 35 to 60° C., in a Soxhlet extraction apparatus for one hour. A battery of six medium sized extractors was found to be convenient. From 14 to 20 twig sections ranging from 4 to 6 centimeters in length and averaging about 5 millimeters in diameter were found to fit nicely in the extractor without using a thimble.

At the end of one hour, the wood is removed and saved for surface area measurements. The greater part of the solvent is recovered in the extractor and the extract transferred with the aid of petroleum ether to a 125 ml. separatory funnel, or to a storage bottle if the extract cannot be analyzed immediately. The dinitro-o-cresol is then recovered from the petroleum ether by shaking with 15 ml. of 0.1 per cent sodium bicarbonate solution. This converts the acid to the sodium salt which is water soluble. The aqueous layer is filtered into a 50 ml. volumetric flask and the ether layer washed with two 10 ml. portions of bicarbonate solution. The washings are transferred to the flask through the filter and the filter paper given a final washing with a little water or bicarbonate solution. A double layer of 9 cm. filter paper was used in this work.

The amount of toxicant extracted can be determined by means of a photoelectric colorimeter or spectrophotometer. In this work a Lumetron colorimeter, model 402E, with a 440 millimicron light filter was used. Transmission measurements are made using a cylindrical cell 50 mm. in length and of 35 ml. capacity. This depth of cell was found necessary in order to determine the lighter deposits encountered in this work. For heavier deposits it is sometimes necessary to make dilutions of the bicarbonate extract to 100 ml. or even to 250 ml. The instrument is set for 100 per cent transmission with the galvanometer at zero, using water in the cell. The water is then removed, the cell rinsed with a little of the solution to be tested and then filled with the toxicant solution. The galvanometer is again adjusted to zero reading and the per cent transmission read.

The amount of dinitro-o-cresol is calculated from a previously constructed graph, figure 1, made by plotting known amounts of the acid against per cent trans-

Eastern Branch Program.

[1] Journal Paper No. 753, New York State Agricultural Experiment Station, Geneva, New York.

[2] This investigation has been aided by a grant from the Dow Chemical Co., Midland, Michigan.

mission. Standards for this graph were made from a stock solution of 100 mgs. of pure dinitro-o-cresol dissolved in petroleum ether and diluted to 1000 ml. with the ether. One hundred ml. of this stock solution, containing 100 micrograms of the acid per ml. was diluted to 500 ml. giving a solution containing 20 micrograms of the acid per ml. Aliquots of this final solution containing 0 to 250 micrograms of dinitro-o-cresol were measured from a burette into 125 ml. separatory funnels and diluted with petroleum ether to about 50 ml. From this point the procedure previously described was followed, the standards being treated in the same manner as the extracted residues.

CALCULATIONS OF TOXICANT PER UNIT AREA OF BARK SURFACE.—The total surface area of the twig sections is calculated from measurements of their lengths and volumes. Total length is determined from the lengths of all the twigs measured in centimeters. Volume is determined by measuring the number of cubic centimeters of water which the entire sample will displace in a graduated cylinder. The total area in square centimeters is calculated from the equation:

$$A = 3.55\sqrt{Vh}.$$

where A is the total area in square centimeters, V the volume in cubic centimeters, and h the length in centimeters. Micrograms of dinitro-o-cresol per 100 square centimeters is calculated by dividing the net micrograms of dinitro-o-cresol by A/100.

Deposit analyses were run on sections taken from twigs which were identical in every respect with those bearing aphid eggs. They were sprayed at the same time with the same equipment. This was true where a power sprayer was used in field tests as well as where a paint gun sprayer was used in green house tests.

EFFECT OF BLANK.—Since petroleum ether removes from plants colored materials, which affect the light transmission in the colorimeter, it is necessary to determine the blank by treating the extract from unsprayed twig sections in the same manner that the extracts of sprayed twigs are treated. This effect, although slight, is nevertheless appreciable and varies somewhat with the different types of wood. Hence, a blank is determined for each type of wood studied. Blank values are read from the curve (Fig. 2) and are calculated as micrograms per square centimeter. The blank for each sample is determined by multiplying this value by the number of square centimeters of bark surface. The net amount of dinitro-o-cresol for the sample is the total micrograms found from the curve minus the blank value. Blanks were found to vary with different plant species from about 0.25–0.80 micrograms per square centimeter.

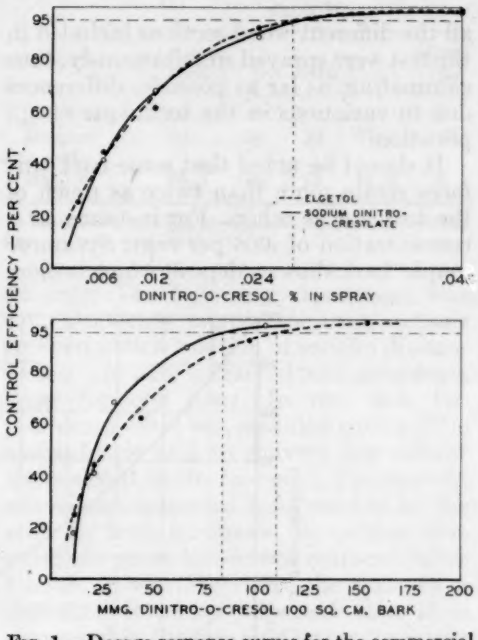

FIG. 1.—Dosage-response curves for the commercial product[1] and the laboratory preparation of the pure sodium salt.

VARIATIONS IN DEPOSIT.—The amounts of dinitro-o-cresol deposited on bark surfaces was found to vary somewhat with different plant species. Table 1 gives the average deposit on duplicate samples of twig sections taken from fifteen different species of plants sprayed with five different concentrations of the toxicant.[2] This insecticide consists of 40 per cent actual toxicant (dinitro-o-cresol), the remainder being wetting agent and filler. The material was applied as a spray using a paint gun type of sprayer at a pressure of approximately 30 pounds per square inch.

For a single concentration of toxicant

[1] *Elgesol.*

[2] The toxicant used in these tests was DN—Dry Mix No. 2 in ordinary city water.

Table 1.—Variations in deposit with different plant species.

Per Cent Concentration	Micrograms of DNOC per 100 Sq. Cm. of Bark Surface — Plant Species[1]														
	B	A	F	E	L	M	R	S	O	N	W	H	C	CB	GB
0.0015	10	8		5		16	10	9	8	11	11	13	16	6	8
0.003	24	19	25	8	18	27	23	21	13	21	16	28	39	13	13
0.006	40	30	42	21	53	55	42	35	26	34	40	43	46	28	27
0.012	74	65	84	48	108	112	85	65	52	53	70	94	95	55	50
0.024	146	150	173	89	198	212	145	141	101	105	148	174	197	101	82

[1] B—buckthorn; A—apple; F—beech; E—euonymus; L—linden; M—sycamore maple; R—Russian olive; S—spiraea; O—oak; N—ninebark; W—willow; H—hazelnut; C—ornamental currant; CB—canoe birch; GB—gray birch.

all the different wood sections included in the test were sprayed simultaneously, thus eliminating, as far as possible, differences due to variations in the technique of application.

It should be noted that some bark surfaces retain more than twice as much of the toxicant as others. For instance, at a concentration of .006 per cent, Sycamore maple[1] bark shows a deposit which is more than twice that of euonymus, canoe birch, or gray birch. Other variations are not as great. Buckthorn and Russian olive show similar deposits. Different plants showing great differences in the character of the bark showed large differences in their depositing characteristics. Maple bark is rough and full of crevices whereas euonymus and the birch barks are smooth and waxy.

[1] The scientific names of the plants referred to are given in Table 1 of the preceding article in this number of the JOURNAL.

Some variations in deposit will be found between samples of the same plant. Table 2 gives a summary of variations in the duplicate analyses from which the averages shown in table 1 were calculated. Of the 146 analyses represented in table 1, all except 3 per cent show less than 15 per cent deviation from the mean of two analyses, while almost 60 per cent show a deviation of 5 per cent or less.

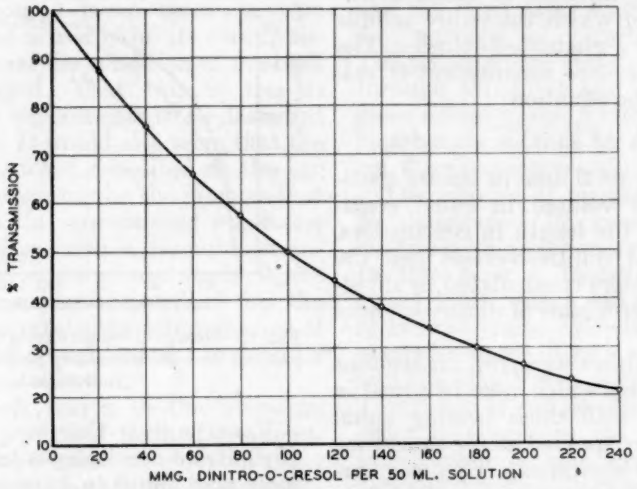

FIG. 2.—Per cent transmission against known concentration of dinitro-o-cresol.

WETTING AGENTS.—All commercial dinitro-o-cresol products now sold contain one or more wetting agents and other adjuvants. As already indicated various commercial products have been compared with laboratory preparations from which all such additives have been excluded. Typical results are illustrated in figure 1.

It will be noted that the efficiency of the two lots is essentially the same when plotted against concentration of toxicant in the spray, whereas, the commercial

product appears to be superior on a deposit basis. The writers interpret this as showing that while the additives cause the laying down of a more evenly distributed but lighter *total* deposit of toxicant on the bark surface (confirmed by microscopic examination) this results in little or no increase in killing efficiency at a given spray strength.

While these data indicate there is no advantage in including a wetting agent or similar additive in aqueous dinitro-o-cresol sprays it should be remembered that the treatments in these tests were applied under almost ideal conditions. The inclusion of a wetting agent is probably advantageous under orchard operations.

DISCUSSION.—The advantage of expressing critical toxicological data in terms of the amount of toxicant deposited on the test subject is perhaps evident. It provides a quantitative basis for comparisons. It should be unaffected by variations in spraying technique. Data based on the concentration of the toxicant in the spray mixture are satisfactory where the same techniques of treatment are maintained. Since it is unlikely that different workers will use identical techniques, however, deposit data would seem to offer a better common basis for comparisons.

A limitation of the use of deposit data has just been presented where the effect of wetting agents was shown.

It is possible that there is a difference in the amount of toxicant deposited on the eggs and the "surface" on which the eggs rest. Whether or not this introduces a significant complication is unknown. However, it probably is not great. The problem is complicated because of the position of the eggs on the host. Some eggs rest on a more or less exposed surface while others are wedged in crevices, scars, or the angle between the bud and stem. In view of this fact, it might appear desirable to remove the eggs from the host before treatment. As pointed out in the preceding article, this technique may introduce serious new complications. We are finally concerned with the behavior of the toxicant on eggs as they naturally occur and, therefore, the writers conclude the method used for deposit analyses is sufficiently accurate for the study undertaken.

There is a final point regarding the method of analysis which should be discussed. The residues were removed from the bark for analysis with petroleum ether. Dinitro-o-cresol is soluble in this solvent while the sodium salt is not. It is therefore necessary to show that petroleum ether effectively removes dinitro-o-cresol from bark surfaces regardless of the form of the toxicant used in the spray mixture. The following experiment was run. Duplicate samples of twig sections sprayed with a solution of sodium dinitro-o-cresylate were extracted with petroleum ether for one hour. In one case the petroleum ether was acidified with a little hydrochloric acid to convert any salts of the toxicant to the free acid. The amount of toxicant extracted was found to be the same in both instances. In neither case could any more toxicant be extracted after 1 hour. In whatever form the toxicant is deposited it seems apparent that it is converted to the free acid either during or before extraction with petroleum ether.

Table 2.—Variations in duplicate analyses for dinitro-o-cresol.

	PER CENT DEVIATION FROM MEAN[1]				
	Less than 1	1–5	6–10	11–15	Over 15
Number of samples	24	60	34	24	4
Per cent of samples	16.5	41	23	16.5	3

[1] The mean of each pair of values and the per cent deviation from the mean were calculated.

SUMMARY.—In connection with a study of dinitro-o-cresol as an aphid ovicide, a method is presented for the determination of the quantity of this toxicant deposited on plant surfaces in spraying. The method consists of removing the toxicant with petroleum ether, converting it to the highly colored yellow sodium salt, and measuring the color intensity by means of a photoelectric colorimeter.

Bark surfaces of different plants sprayed with the same spray mixture gave widely varying deposits. A discussion of the application of deposit data is presented.

Wetting agents were found to influence the gross distribution of the toxicant over the bark surface, but apparently did not influence the rate of kill at parallel concentrations.—2-26-48.

Experiments on Control of the Eastern Raspberry Fruitworm[1]

F. G. Mundinger, *New York State Agricultural Experiment Station, Geneva*

The eastern raspberry fruitworm, *Byturus rubi* Barber, commonly found in most New York State red and purple raspberry plantings, was unusually destructive in 1944. Raspberries examined at processing plants that year were found to be heavily infested with larvae, and field inspections of plantings in central and western New York showed that in some instances more than 50 per cent of the berries were "wormy." While profits from raspberry growing, especially during recent years, were sufficient to encourage the use of insecticides for the suppression of the few early summer pests, a relatively small number of growers followed a definite insecticide program and since some difficulty was experienced in controlling the fruitworm with the standard insecticides, this investigation was begun to determine the effectiveness of new control materials, and the more exact timing of treatments through correlation with the stages in plant development.

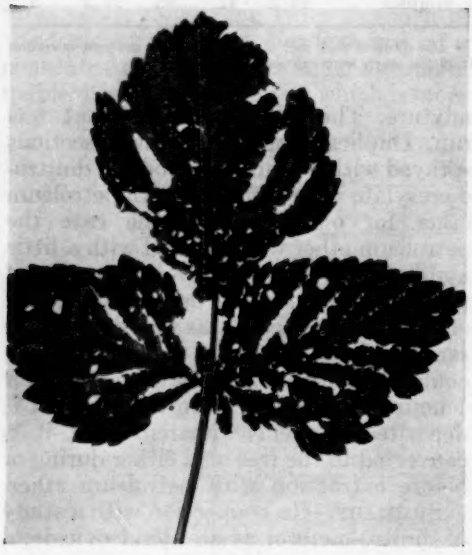

Fig. 1.—Raspberry leaf showing feeding injury by *Byturus rubi*.

Eastern Branch Program.

[1] Journal Paper No. 747, New York State Agricultural Experiment Station, Geneva, N. Y., January 19, 1948.

Injury.—*Byturus rubi* injures the leaves and fruiting parts of the plants especially the blossom buds, the receptacles and frequently the carples of the berry. Leaf injury (Fig. 1) results from the feeding of the adults and consists of holes eaten through the young leaves. In heavily infested plantings the foliage may be severly damaged especially during seasons unfavorable for the rapid development of the blossom buds. Since cane borers and certain other insects also feed chiefly on raspberry foliage, a high increase in the population of any one of these species may seriously devitalize the plants. Injury to the blossom clusters is probably the most important commercially and the least frequently observed. The beetles in feeding on the pedicles of the blossom buds frequently sever one or more of them and occasionally the entire cluster is cut off. They also attack the individual blossom buds (Fig. 2, left) eating out large holes through which they enter and feed on the floral parts. While in the larval stage *Byturus* attacks the receptacle and the carples of the berry. It makes a tortuous tunnel through the receptacle (Fig. 2, center) frequently reducing the structure to a decayed mass from which the berry loosens and drops. In feeding on the carples, the larva not only injures the fruit but leaves damaged tissue in which destructive fungi usually develop. The presence of larvae in harvested fruit is more often than not the first indication of the presence of the pest in the planting and its commercial importance is estimated by the value of fruit rejected because of worminess at the time of sale. The loss of production because of injury to the fruiting parts is usually not considered.

Life Stages.—The egg (Fig. 3, left) of *Byturus* is grayish white in color, about 1.1 mm. long, somewhat ovoid in shape and tapering to a point at each end. The newly hatched larva is slender, nearly uniformly white in color and scarcely distinguishable from the flesh of the receptacle. When full grown it is about 4 mm. long and bears silver-gray markings on

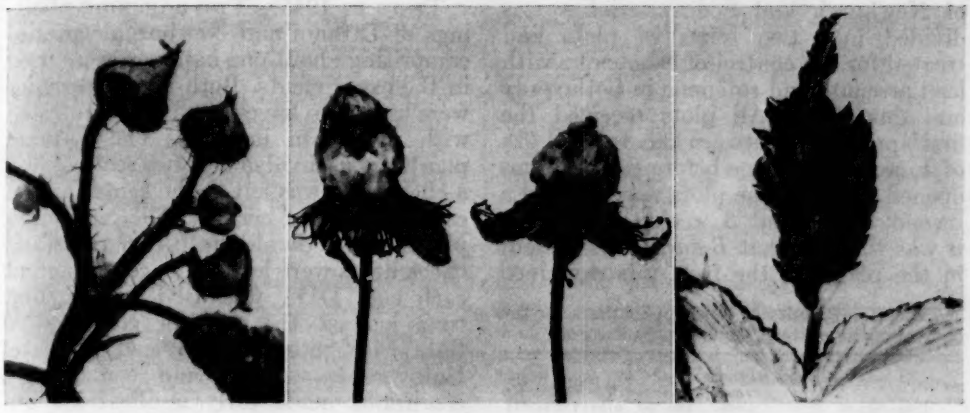

FIG. 2.—Left: Blossom buds showing injury from beetle feeding. Center: Receptacles injured by (×1½). Right: Adults feeding on leaf (×1½)

the dorsal and lateral portions of the abdominal segments (Fig. 2, right). The adult (Fig. 3, right) is a light brown beetle about 3 mm. long, somewhat stout and covered with a yellowish white pubescence.

SEASONAL HISTORY AND HABITS.—The beetles begin to emerge from the soil during late April and early May about the time the first leaves of the Latham raspberry are beginning to unfold and are most commonly found on the midrib of the young leaf wholly or partially concealed. After the leaves expand and flatten out they seek further protection and new feeding grounds in the spaces among the lengthening pedicles of the blossom buds. Later on when these have separated the insects are forced to feed more or less in the open and they frequently attack the swelling buds. Maximum oviposition takes place during the pre-blossom period, most of the eggs being laid on the enlarged blossom buds commonly along the tips of the sepals, but a few may be placed inside the buds and some are occasionally found on the young fruit. The beetles become scarce about the second week in June, though they were taken in the field in 1946 as late as July 1. On hatching, the larva makes its way toward the base of the young fruit where it burrows frequently through a sepal and on into the receptacle of the berry. Most of the larvae mature probably about the middle of July after which they go to the ground where pupal cells are constructed one half inch or so below the surface.

CONTROL TESTS.—Since the laws of New York State prohibit the use of toxic substances on plants while they are in bloom, the control tests in most cases were made during the preblossom period. Several varieties of raspberries, namely, Latham, Newburgh, Marcy, Taylor, Sodus and Indian Summer were used in the work. All dusts were applied by hand but the sprays were put on with power equipment. The experimental plots varied from 30 to 125 feet in length and were from 4 to 6 rows wide. In most of the experiments duplicate plots were used. The effectiveness of the materials was determined by the number of wormy berries found at harvest time. Usually two series of counts were made in each plot, the first at the beginning of harvest, and the second from 10 to 12 days later. From 600 to 1000 berries were examined for determining the results of each treatment.

TESTS IN 1940.—A planting comprising about one-fourth of an acre and consisting

FIG. 3.—Left: Blossom bud with egg of *Byturus* near tip (×5). Right: Receptacle with full-grown larva in shallow feeding groove (×1½).

of Newburgh and Sodus varieties was divided into two series of plots and treated for the control of caneborers with lead arsenate and rotenone in both spray and dust form. All plots received the first application between the 3rd and 6th of June, a short time before the blossoms opened. Some of the plots were treated a second time about 3 weeks later. Since it was thought that *Byturus* was present in the planting, the fruit was examined for worminess at harvest time. The results are shown in tables 1 and 2. These data were derived from one series of counts and the calculated reductions are therefore probably too high to be truly representative of the results. It will be noted that one rotenone treatment, either spray or dust, gave greater reductions than one lead arsenate treatment, and that a second application did not materially affect the results except in the case of lead arsenate. The good weather conditions during the time of the treatments and the light infestation were probably favorable factors in securing the high control efficiencies.

Table 1.—Results of dust applications for the control of the eastern raspberry fruitworm.

Insecticide	Date of Application		Planting No.	Variety†	Per Cent Reducton
	1940				
	June	June			
Rotenone 1%	3			N	97.4
Rotenone 1%	3	22		N	100.0
Lead arsenate-lime 20%	3			N	89.8
Lead arsenate-lime 20%	3				
Rotenone 1%		22		N	100.0
	1946				
	May	May			
Rotenone 1%	2	28	1	L	89.7
Rotenone 1%		28	1	L	77.5
DDT 3%	2	24	1	L	90.6
DDT 3%		24	1	L	92.3
DDT 5%	2	25	1	L	81.4
DDT 5%		25	1	L	92.8
DDT 3% and Velsicol	2	28	1	L	86.2
DDT 3% and Velsicol		28	1	L	75.8
DDT—Pyrethrum Spec.*	15	June 3	2	N	71.6
DDT—Pyrethrum Spec.*	15	3	2	N	33.5
Lead arsenate-lime 10%	2	24	1	L	61.8
Lead arsenate-lime 10%		24	1	L	63.2
Lead arsenate-lime 10%	16	3	2	N	62.0
	1947				
	May	June			
Rotenone 1%	26	10	1	L	96.3
Rotenone 1%	27	13	2	L	90.8
Rotenone 1%	28	13	3	N	89.2
DDT 3%	26	10	1	L	98.3
DDT 3%	27	13	2	L	94.4
DDT 3%	28	13	3	N	91.1
DDT 5%	26	10	1	L	96.8
DDT 5%	27	13	2	L	92.6
DDT 5%	28	13	3	N	85.9
Lead arsenate-lime 10%	27	10	1	L	87.3
Lead arsenate-lime 10%		7	1	L	74.2

* Commercial mixture
† N—Newburgh; L—Latham.

TESTS IN 1945.—Two adjoining plantings of Latham and Newburgh varieties comprising about one-half acre were used in the experiments. Both of the varieties were known to have been heavily infested with fruitworm in 1944. The Latham planting was divided into two sections and a check area was left in the center and in each of the four corners. The Newburgh planting was divided into four plots and check areas were left in the center and at each end. DDT was used for the first time against the pest in comparative tests with rotenone and lead arsenate. Unfavorable weather and wet ground conditions made early applications impossible so that only one series of treatments was made, just as the blossom buds were beginning to open. As shown in table 2, both DDT and rotenone were more effective than lead arsenate, however the reductions in fruit worm population were not sufficiently high for control. The delay in the application of the treatments and the unfavorable weather conditions following the treatments contributed toward the low reductions.

TESTS IN 1946.—In 1946 4 plantings comprising about 3 acres were used in the tests. Dusts were applied to planting No. 1 consisting of the Latham variety on May 2, about the time the first blossom buds were visible. On May 24 when the blossom buds seemed ready to open, the treatments were repeated on the first series of plots, and the same mixtures applied to a second series. Three check areas were left in the planting, one at each end and one at the west side. The data, table 1, show that both DDT and rotenone gave rather great reductions in the number of wormy berries. Lead arsenate was not so effective. There was very little difference in the control between plots receiving one and two applications except in the case of rotenone and DDT with chlordan. This might indicate that the second treatment was early enough under the conditions prevailing to give fair control. However, high winds on the day following the applications doubtless carried some of the dust materials from treated to untreated plots. This may account in part for the small differences in control between plots treated once and those treated twice. Beetles were seen as early as April 24 and a few blossom bud were found on May 2, but development

was very slow resulting in a long preblossom period favorable for extensive oviposition. Planting No. 2 consisting of the Newburgh variety also was divided into two sections, one of which was dusted and the other sprayed. Check areas were left in the four corners of each section. The first dust treatment was applied on May 15 a short time after the blossom buds began to show, and the second treatments were made June 3, about the time the first blossoms were beginning to open. The data in table 1 show that none of the treatments were satisfactory. Lead arsenate, however, gave about the same control as in the previous tests, indicating that the timing was correct but that the materials as used were not sufficiently effective for control. The sprayed section was treated on May 23, the application being unavoidably delayed and as a result the reduction percentages were low. Rainy conditions in this area during the latter half of the month were most unfavorable for good control. In planting No. 3 consisting of Marcy and Taylor varieties, a series of sprays was applied in which DDT was again compared with rotenone and lead arsenate. Fruit worm infestation was known to have been fairly heavy in 1945. The section comprising the Marcy variety was at the north end of the planting and that having the Taylor variety was at the south end. Check areas were left in the center of each section and in the four corners of each. The first series of sprays was applied to both sections on May 9, after the blossom buds had begun to show and the second on May 29, shortly before they opened. Table 2 shows that the DDT and rotenone treatments again were more effective than the lead arsenate. The reductions in wormy fruit however were not so high as those of planting No. 1. It is very possible that the central check plots served as additional dispersions points from which beetles could travel in all directions and

Table 2.—Results of spray applications for the control of the eastern raspberry fruitworm.

INSECTICIDE—AMOUNTS PER 100 GALLONS	DATES OF APPLICATION		No.	PLANTING VARIETY[2]	SECTION	PER CENT REDUCTION
	June *1940* June					
Derris 5 lbs.	6	26		S		98.7
Derris 5 lbs.	6	26		N		97.4
Lead arsenate 6 lbs.	6			S		91.0
Lead arsenate 6 lbs.	3					
Rotenone dust 1%		26		N		100.0
	May *1945*					
Cube 5 lbs.[1]	18			L		72.1
Cube 2.5 lbs.	21			L		23.3
DDT .5 lb.	18			L		72.2
Lead arsenate 4 lbs.	21			L		45.9
	May *1946* May					
Cube 5 lbs.	9	29	3	M	1	73.4
Cube 4 lbs.	9	29	3	T	2	59.3
DDT .5 lb.		23	2	N		58.3
DDT .5 lb.	9	29	3	M	1	87.8
DDT 1lb.	9	29	3	T	2	84.1
Lead arsenate 4 lbs.		23	2	N		39.6
Lead arsenate 4 lbs.	9	29	3	M	1	62.1
Lead arsenate 4 lbs.	9	29	3	T	2	56.0
Benzene hexachloride 2 lbs.		23	2	N		60.3
	May *1947* June					
Cube 5 lbs.	31	12	3	T		98.3
DDT .5 lb.	31	12	3	T		88.3
DDT 1 lb.	31	12	3	T		93.6

8 oz. of skim milk powder per 100 gallons used for spreader in 1940.
8 oz. commercial spreader per 100 gallons used for spreader in 1945.
1 pint summer oil per 100 gallons was used for spreader in 1946 and 1947
[1] Cube 5% rotenone except in 1946 tests.
[2] S—Sodus; N—Newburgh; L—Latham; M—Marcy; T—Taylor.

reinfest adjoining plots. Weather conditions as stated above were not favorable for optimum control.

The fourth planting treated was small and not suitable for extensive tests, but since it had never been sprayed or dusted for the control of the fruit worm, and was known to have been heavily infested, DDT rotenone and lead arsenate were applied to duplicate plots. Dying plants in the check areas and in some of the treated plots made it impossible to secure dependable data on the various mixtures used but the average infestation was around 5 per cent this season, while the previous year it was over 40 per cent. The DDT and the rotenone plots showed the best control.

TESTS IN 1947.—About three acres of raspberries, all moderately infested in 1946, were used in the experiments in 1947. Planting No. 1 was oblong in shape with check areas at each end and consisted of the Latham variety. Two applications each of DDT, rotenone and lead arsenate dust were made on all plots except two which received one treatment of the lead arsenate. The first applications were made on May 27 when the blossom buds were beginning to show and the second on June 10, shortly before bloom. As shown in table 1 both DDT and rotenone gave large reductions in wormy fruit. Two lead arsenate dusts were fairly effective and one treatment made after the cluster buds had separated gave 74.2 per cent reduction. In planting No. 2, also of the Latham variety, some of the same mixtures were repeated. The first applications were made on May 27 and the second on June 13. Check areas were left in each of the four corners. The results shown in table 1 compare very favorably with those of the tests in planting No.1. Planting No. 3, a long, narrow patch with check areas at each end and consisting of the Newburgh variety, was also treated with the same dust mixtures. The first treatments were made on May 28 and the second on June 13. They were not duplicated. While the reductions in wormy fruit were not so great as in either of the other plantings, they were satisfactory for control and compared favorably with those of the previous tests. Planting No. 4, consisting of the Taylor variety, was laid out with checks in each of the four corners and all plots were sprayed twice. The first application was made on May 31 and the second on June 12. The results as shown in table 2 are similar to those secured with dusts. While the 1947 season was unusually wet, most of the experimental plots escaped damage by the rains.

CONCLUSIONS.—The tests show that DDT used at the rate of 1 pound in 100 gallons of spray with a suitable spreader or applied in dust form at 3 or 5 per cent dilution gave the highest reductions in infested fruit of all the materials tried. Ground derris or cube root, 5 pounds in 100 gallons of spray or diluted to a 1 per cent dust was also very effective. Lead arsenate in almost all tests gave lower reductions than DDT or rotenone. While during some seasons such as 1940 and 1946 commercial control was obtained with one treatment, two treatments are advised. Where DDT or rotenone are used, the first application should be made just after the blossom buds appear and the second a few days before bloom. These materials being both contact insecticides and stomach poisons have a distinct advantage over lead arsenate. This insecticide when applied especially in a spray is probably more efficient if used after the blossom buds have separated so that it reaches all surfaces of the cluster buds. In practically all tests dusts were more effective than sprays. Since blossom bud development varies according to the variety of raspberry and also with the season and since the early activities of the beetles appear to be closely correlated with bud development, a variety such as Latham, Taylor or Newburgh, not too early in maturing fruit, may be used as an index for timing the control applications. Where two treatments are made there seems to be considerable latitude in timing. The maintaining of a protective cover during a period of at least two weeks before the blossoms open is necessary for control. Protection from injury by the insect is secured with greater difficulty in seasons having a long preblossom period, since the insecticidal cover must be maintained longer, and conditions are favorable for more extensive oviposition. It is important that the sprays and dusts be directed into all crevices between the leaf blades and among the cluster buds.

Experiments for Control of the Grape Leaf Folder in California

NORMAN W. FRAZIER[1] and DWIGHT F. BARNES[2]

The grape leaf folder, *Desmia funeralis* (Hbn.), is considered to be one of the secondary grape pests in California, but in some restricted areas it often causes heavy damage. The accepted methods of control have been the use of lead arsenate sprays, arsenical dusts, or dusts containing cryolite (sodium fluoaluminate). In recent years cryolite dusts have been used almost exclusively. Excellent results have been secured when the applications were properly timed. Since the inorganic poisons, arsenic and cryolite, are restricted in their use to the early part of the season, some of the newer organic insecticides have been tested in the field by the writers to compare their effectiveness with cryolite for control of the grape leaf folder. The tests were made on Emperor grapes in Tulare County.

EXPERIMENTS IN 1946.—In the spring of 1946, during the feeding period of the first-brood larvae, a dust composed of 45 per cent of cryolite and 55 per cent of sulfur was compared with one composed of 5 per cent of DDT, 50 per cent of sulfur, and 45 per cent of filler. Both dusts were applied at the rate of 20 pounds per acre. The DDT-sulfur dust did not control the leaf folder. The cryolite-sulfur dust was effective and gave control for the entire season; redusting when the second brood was feeding did not increase its effectiveness. More foliage was eaten when the cryolite-sulfur dust was applied during the feeding period of the second brood than when the application was made for control of the first brood.

Dusts containing 0.75 per cent gamma isomer of benzene hexachloride,[3] 5 per cent chlordan or 5 per cent xanthone and 50 per cent sulfur were tried during the feeding period of the third brood in September 1946. Three weeks after the dustings there were less than 50 per cent as many larvae in the rolls on vines treated with the gamma isomer and chlordan dusts as on the untreated vines.

EXPERIMENTS IN 1947.—Tests with the 9 dusts listed below, each of which contained sulfur so that it could be used in place of a regular sulfur dusting for powdery mildew control, were made in 1947 during the feeding period of the first brood grape leaf folder larvae.

1. Xanthone 5 per cent, sulfur 50 per cent.
2. Chlordan 5 per cent, sulfur 50 per cent.
3. Gamma isomer 0.75 per cent, sulfur 50 per cent.
4. Cryolite 50 per cent, DDT 5 per cent, sulfur 40 per cent.
5. DDD 5 per cent, sulfur 50 per cent.
6. Chlorinated camphene 5 per cent, sulfur 50 per cent.
7. DDT 5 per cent, sulfur 50 per cent.
8. Di-2-ethyl hexyl phthalate 3.3 per cent, sulfur 33.3 per cent.
9. Parathion 1 per cent, sulfur 55 per cent.

The plots were 6 rows wide and 77 vines long, each a little over an acre in size. Eight plots were dusted on April 17, shortly after the hatching of grape leaf folder eggs began. Nine other plots were dusted on April 30, when the larvae were entering the third stage. A tractor-mounted duster was used to apply the dusts and both sides of each row were dusted.

On May 19 and 22, 3 to 4 weeks after the treatments, when all larval stages were present, observations were made to compare the effectiveness of the dusts that had been used. The number of feeding spots and leaf rolls, and the number of larvae in them were recorded for 5 vines in each plot. The vines were located in the 3 middle rows. The plots dusted with cryolite-DDT-sulfur or with parathion-sulfur dust mixtures were reexamined 6 or 7 weeks after treatment. At that time, June 12, the first brood activity was practically complete and most of the leaf rolls were empty. The total number of rolls on 6 vines was recorded. Vines 5 and 10 in rows 3, 4 and 5 of each plot were selected for examination.

Previous to 1947 no satisfactory method of comparing the effectiveness of different treatments had been worked out. The larval habit of feeding within the protection of the webbed-together leaves in the early stages and of occupying more than

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[3] The term "gamma isomer" will be used for gamma isomer of benzene hexachloride in the rest of the paper.

one roll in the later stages had confused observers. The data secured on May 19 and 22 was examined after it was arranged to show the average number of larvae per feeding spot, per roll, per vine in feeding spots, per vine in rolls, and per vine in feeding spots and rolls combined. The average number of larvae in rolls per vine shown in table 1 appeared to be the most satisfactory basis for estimating the effect of the treatments since these larvae had survived exposure to treated foliage until they were approaching maturity.

Table 1.—Average number of larvae per vine in leaf rolls on five vines in plots treated for grape leaf folder control, Exeter, Calif., April 1947.

Composition of Dusts	Dosage (Pounds per Acre)	Rolls on Vines Examined (Number)	Larvae in Rolls per Vine (Average)
Group 1, dusts applied April 17 and vines examined May 19			
Cryolite-DDT-sulfur	20	7	1.6
Xanthone-sulfur	20	31	6.4
Chlordan-sulfur	30	36	9.0
Gamma isomer-sulfur	20	49	10.6
Chlorinated camphene-sulfur	30	71	15.6
Di-2-ethyl hexyl phthalate (899)-sulfur	30	78	17.2
DDD-sulfur	20	111	25.0
Check, untreated		173	35.8
DDT-sulfur	20	184	45.4
Group 2, dusts applied April 30 and vines examined May 22			
Parathion-sulfur	20	9	2.0
Cryolite-DDT-sulfur	20	11	2.4
Gamma isomer-sulfur	20	43	8.6
DDT-sulfur	20	91	18.2
Chlordan-sulfur	20	120	27.4
DDD-sulfur	40	149	35.0
Check untreated		173	35.8
Chlorinated camphene-sulfur	20	158	38.4
Di-2-ethyl hexyl phthalate sulfur	12	196	44.8
Xanthone-sulfur	20	388	86.2
Average of groups 1 and 2			
Parathion-sulfur (1 plot of 5 vines only)		9	2.0
Cryolite-DDT-sulfur		18	2.0
Gamma isomer-sulfur		92	9.6
Chlordan-sulfur		156	18.2
Chlorinated camphene-sulfur		229	27.0
DDD-sulfur		260	30.0
Di-2-ethyl hexyl phthalate-sulfur		274	31.0
DDT-sulfur		275	31.8
Check, untreated (1 plot of 5 vines only)		173	35.8
Xanthone-sulfur		419	46.3

It was evident from the figures in the table that two of the dust mixtures, cryolite-DDT-sulfur and parathion-sulfur, were outstanding. An average of 2 larvae per vine was found in rolls in plots treated with these dusts while the average was 35 per vine in the untreated check. The gamma isomer and chlordan dusts also appeared to be promising. The other treatments were not encouraging.

When the plots treated with cryolite-DDT-sulfur and parathion-sulfur dusts were examined on June 12 it was evident that some of the larvae that were feeding between the webbed-together leaves at the time of the first examination had survived and had made rolls. The largest increase occurred where the parathion-sulfur dust was used. It appeared that the parathion lost its effectiveness before the brood completed its feeding and that another application of the dust would have been necessary to maintain control. No recommendation can be made for the use of parathion on grapes until more is known about the possible residue hazard.

SUMMARY AND CONCLUSIONS.—Several of the newer organic insecticides were compared with cryolite for use in controlling the grape leaf folder, an insect which causes serious damage to grapes in limited areas in California. All of the insecticides were mixed with sulfur so that the dusts might be substituted for one of the regular sulfur treatments for powdery mildew control.

A dust containing 5 per cent DDT and 50 per cent sulfur, a mixture that is used for grape leafhopper control, was compared with a 45 per cent cryolite-55 per cent sulfur dust in 1946. In 1947 a dust containing 50 per cent cryolite, 5 per cent DDT, and 40 per cent sulfur, which was designed to control the grape leaf folder grape leafhopper and powdery mildew, was compared with 8 other dusts containing organic insecticides and sulfur.

The number of larvae in rolls per vine toward the end of the brood for which treatments were applied proved to be a satisfactory basis for determining their effectiveness.

The best results were secured with the dusts containing cryolite or parathion. The tests with parathion, however, indicated that more than one application of the material will be required to control one brood of grape leaf folder larvae. The possible use of parathion in practical control of the grape leaf folder will depend on the residue hazard, not yet.

There was little difference in the control obtained with cryolite dust whether it was applied at the start of hatching or at the beginning of leaf rolling of the same brood.

The larvae of the grape leaf folder were not controlled by a dust mixture containing 5 per cent of DDT unless cryolite was also present.

This progress report does not constitute a recommendation of any of the materials tested, other than cryolite, and these results may or may not be used as a basis of recommendation to the grower.—4-30-48.

Pear Psylla Control with Dormant Sprays[1]

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The value of dormant spray applications for control of the pear psylla, *Psylla pyricola* Foerst., has been known for a long period. Hodgkiss (1914) published on the use of nicotine and soap and concentrated lime-sulfur sprays for the control of this insect. From 1925 to 1930 dormant oil sprays began to be generally used for this purpose, and soon replaced the materials used previously. Mundinger (1943) reported on results obtained with dinitro insecticides. This paper gives information on the control of pear psylla obtained in field tests with dormant sprays during the last five years.

The materials used included dormant-type and summer-type oils, dinitro insecticides, DDT, and benzene hexachloride. Unless otherwise indicated, all the oils were emulsified in the spray tank with 8 ounces of blood albumin[2] per 100 gallons of spray. Each field plot consisted of blocks of trees at least 4- by 5-tree rows in size located in a commercial orchard having a heavy population of adult psyllas. From 1943 through 1946 the plots were unreplicated. However, in 1943 most of the treatments were duplicated in a second orchard, and in 1947 all the treatments were applied to duplicate plots. The varieties Clapp Favorite, Kieffer, and Bartlett were used at different times, but each series of tests was confined to a single variety. Counts of first-brood nymphs were made on 15 spurs from each of 2 to 4 trees in the center of the block just before the adults emerged. From 1943 through 1946 the spurs were preserved in formalin and examined later in the season. In 1947 the counts were made immediately after the spurs were cut.

OIL SPRAYS.—To be most effective, oil sprays must be applied after most of the hibernating adults have moved to the outer part of the trees and before they have laid many eggs. The adults emerge from hibernation when the temperature rises to 50° F., and egg laying usually starts a few days later. An oil spray applied during this short period will kill most of the adults present and may inhibit oviposition by females that survive the treatment. In addition, some of the young psyllas that hatch later die from the action of the oil either on the egg or on the young nymph.

The need for careful timing of dormant oil sprays was demonstrated in 1945. Pear trees sprayed with a 3 per cent oil emulsion on March 24, after most of the psyllas had come out of winter quarters but prior to the start of egg laying, averaged 0.3 first-brood nymph per spur, whereas trees given the same treatment 4 days later, after heavy egg laying occurred, averaged 1.3 first-brood nymphs per spur. Unsprayed trees averaged 7.8 nymphs per spur.

In 1943 dormant oils having viscosities of 200 to 215 and 90 to 120 seconds Saybolt (at 100° F.) were about equally effective and caused no injury when used at a concentration of 3 per cent. First-brood nymphs averaged 0.06 and 0.01 per spur in two plots sprayed with the heavier oil, as compared with none in two comparable plots sprayed with the lighter oil. In 1947 comparison of a 100-second dormant-type with a 60-second summer-type oil again indicated that, within limits, the viscosity of an oil is not an important factor affecting its efficiency in dormant applications against the pear psylla. Likewise in 1943, 100-second oils with a high naphthenic or a high paraffinic base were equally effective. Both types gave complete control of first-brood nymphs in two tests. These results indicate that any oil of the types generally used in dormant sprays and some, at least, of those used in summer sprays can be employed effectively and safely in dormant sprays applied to control of the pear psylla. However, since Pearce and Chapman (1947) have shown that paraffin-base oils of certain specifications are superior to others for the control of certain insects and are likely to be less toxic to the host, it is suggested that oils within the range of those recommended by these workers be employed in pear psylla sprays.

In 1944, 1945, and 1947 a spray con-

[1] The work reported herein was conducted at Poughkeepsie, N. Y., in cooperation with the New York (Geneva) Agricultural Experiment Station. Acknowledgments are particularly due J. L. Brann, Jr., who participated in the tests made during 1947.

[2] A proprietary material containing 25 per cent of actual blood albumin.

taining 2 per cent of a 100-second dormant-type oil was compared with one containing 3 per cent. Since the two strengths proved to be about equally effective, 2 per cent seems to be adequate for pear psylla control unless a higher strength is needed for the control of other orchard pests, such as the European red mite, *Paratetranycus pilosus* (C. and F.), and certain scale insects.

DINITRO SPRAYS.—Insecticides containing dinitro-*o*-cresol or its salts or dinitro-*o*-*sec*-butyl phenol proved to be highly effective in the control of the pear psylla when applied after maximum egg laying had occurred and before green tissue began to show. They killed a high percentage of the eggs, but had little effect on the adults. Because of danger of injury to foliage, these materials must be applied before the buds show green tissue. In some years bud development is rapid and the time for application of dinitro sprays is limited. The increase in effectiveness when the application of dinitro sprays was delayed until just before the fruit buds burst was demonstrated in 1944. Trees sprayed with 0.5 per cent of a liquid containing approximately 20 per cent of sodium dinitro-*o*-cresylate on April 11 had 1.9 first-brood nymphs per spur, while those sprayed on April 18 had only 0.4 nymph per spur. Maximum oviposition occurred between the two applications. Unsprayed trees averaged 7.9 nymphs per spur.

Good commercial control has been obtained with as little as 2 quarts of the liquid dinitro materials indicated above, and in some instances with 2 pounds of a powdered dinitro-*o*-cresol (40 per cent), per 100 gallons of spray. The liquid material has been consistently better than the powdered, perhaps because a penetrant is present in the liquid formulation. One or 2 quarts per 100 gallons of a liquid containing 25 per cent of dinitro-*o*-*sec*-butyl phenol and triethanolamine was as effective as the sodium dinitro-*o*-cresylate except in one test in 1947. In this case control was almost complete in one replicate, whereas it was very poor in the other. A formulation containing 5 per cent of the sodium salt and 15 per cent of the ammonium salt of dinitro-*o*-cresol also gave good results when used at the rate of 2 quarts per 100 gallons of spray.

In 1947 the ovicidal value of the dinitro sprays was determined by caging a large number of pear psylla eggs on trees in three of the dinitro plots immediately after they were sprayed. The treatments and results are indicated in table 1. In every instance less than 10 per cent of the eggs on the treated trees hatched, whereas nearly all of those on the unsprayed check trees hatched.

Table 1.—Effect of liquid dinitro sprays on pear psylla eggs, 1947.

MATERIAL	QUARTS PER 100 GALLONS	PER CENT EGGS HATCHED
Sodium-dinitro-*o*-cresylate:		
20 per cent	2	9.8
5 per cent plus ammonium dinitro-*o*-cresylate 15 per cent	2	4.4
Dinitro-*o*-*sec*-butyl phenol 25 per cent plus triethanolamine	1	8.8
	2	3.0
Unsprayed	0	98.3

COMBINATION OIL-DINITRO SPRAYS.—In order that both adults and eggs of the pear psylla would be killed, combination sprays containing both dormant oil and dinitro materials were tested in four of the five years. The danger of injury was minimized by using maximum strengths of 2 per cent of dormant oil (emulsified in the spray tank with 4 ounces of blood albumin) and 2 quarts of liquid sodium dinitro-*o*-cresylate (20 per cent) or 2 pounds of a powdered dinitro-*o*-cresol per 100 gallons. In every instance these combination treatments gave excellent control. It ranged from no nymphs per spur in the treated plot and 1.7 in the unsprayed plot in 1943, to 0.2 nymph per spur in both treated plots and 7.8 in the untreated plot in 1945. Except in 1945, when these sprays were applied when the buds were in the early-green-tip stage, no injury occurred. In 1945 the formulation that included the powdered dinitro caused more severe injury than the one that included the liquid dinitro material. For this reason the liquid sodium dinitro-*o*-cresylate is considered safer than the powdered form for use with oil.

Dinitro sprays containing ammonium salts or their derivatives and dinitro-*o*-*sec*-butyl phenol plus triethanolamine were not used in combination with oil.

Since such salts are known to be more caustic to the trees than those containing sodium-dinitro-*o*-cresylate, they should only be used with oil when experimental evidence that they are noninjurious to the host is available. Since sprays containing oil and sodium dinitro-*o*-cresylate are effective against both adults and eggs, they may be applied at any time between emergence of adults from hibernation and the appearance of green tissue on the buds.

The oil, dinitro, and combination sprays all gave a reduction in infestation sufficient for commercial control throughout the season in 1943, 1944, and 1945, when weather conditions were not especially favorable for psylla development. In 1946 and 1947, when conditions were unusually favorable to the psylla, the reduction effected by these dormant sprays was not enough to prevent the development of psylla populations to the point where summer sprays were not needed.

DDT.—A spray containing 2 pounds of 50 per cent DDT wettable powder to 100 gallons was applied to an isolated pear orchard in October 1944. Visual examination indicated that this treatment did not control either the adults or the nymphs. Weekly captures of psyllas on sticky-board traps were as large during the 20 days following the application as they had been prior to it.

BENZENE HEXACHLORIDE.—In 1946 benzene hexachloride was used at the rate of 3 pounds to 100 gallons for the control of psylla adults after they had emerged from hibernation but before they had started laying eggs. The gamma isomer content of the benzene hexachloride used was approximately 5 per cent. With this treatment the reduction in population was only 61 per cent, whereas with a 3 per cent dormant oil applied at the same time it was 98 per cent. These results were based on the number of first-brood nymphs subsequently found on spurs in treated plots as compared with the number on spurs in the untreated plot. They indicate that benzene hexachloride is not so promising in dormant sprays as in summer sprays (Hamilton 1947).

SUMMARY.—Field tests of dormant sprays for control of the pear psylla, *Psylla pyricola* Foerst., were made near Poughkeepsie, N. Y., from 1943 to 1947. When properly timed, sprays of oil emulsion, dinitro materials, or combinations of the two gave excellent control of the pear psylla early in the season. Thorough spraying in the spring before green tissue began to show retarded pear psylla build-up in seasons ideal for development of the insect, as in 1946 and 1947, and maintained commercial control throughout the season in years when seasonal conditions were less favorable for psylla development, as in 1943, 1944, and 1945.

Oils ranging in viscosity from 90 to 200 seconds Saybolt (at 100° F.) were about equally effective at a concentration of 3 per cent. No differences were found in the control obtained between oils of high paraffinic and high naphthenic base. A 2 per cent strength of a 100-second oil was about as effective as one of 3 per cent.

Combinations of a 2 per cent dormant oil with 0.5 per cent of sodium dinitro-*o*-cresylate spray material containing 20 per cent of the salt gave excellent control of both adults and eggs. Use of such a combination allows a longer period in which to make the late dormant application.

DDT (50 per cent wettable powder) at 2 pounds to 100 gallons and benzene hexachloride (5 per cent gamma isomer) 3 pounds to 100 gallons were ineffective when used to reduce the populations of adult psyllas present during the dormant season.

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Oriental Fruit Moth Cocoon Parasites

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That cocoon parasites reduce oriental fruit moth, *Grapholitha molesta* (Busck), populations has been recognized by various research workers. Little information has been published, however, on the extent of the reduction and the species involved. Haeussler (1930), Eddy & Nettles (1931), McConnell (1932), and Stearns (1934) mentioned species that had been reared from cocoons, but no data were submitted on the degree of parasitization. Driggers (1932) observed that 271 hibernacula collected from peach trees at four localities in New Jersey in 1928 and 236 from the same localities in 1929 were parasitized, largely by cocoon parasites, to the degree of 66 per cent and 30 per cent (averaged), respectively. Nettles (1934) stated that 58 cocoon parasites and 46 oriental fruit moths emerged from cocoons collected from peach fruits and fruit spurs in South Carolina. Further data on cocoon parasites of the oriental fruit moth are presented in this paper. Intermittent observations were made during 7 years from 1931 to 1945. Although the greater part of the work was done in New Jersey, records were obtained from seven other States.

Methods.—The data are based on cocoons exposed or trapped in peach orchards. Since some species of parasites attack only the prepupal or pupal stages of the host and others attack both stages, the term "cocoon parasite" is used throughout this paper to designate the parasites that attack the oriental fruit moth in different stages within cocoons.

In 1931 records of parasitization were obtained from cocoons formed in trap bands of corrugated cardboard placed around the trunks of trees in orchards in seven counties in New Jersey and two in Pennsylvania. In 1932 similar records were made from trap bands placed in orchards in a total of 26 counties in eight eastern states. Only one band was placed on each tree. The bands were allowed to remain on the trees from about three weeks to two months, after which they were removed to Moorestown, N. J., where the corrugations bearing cocoons were cut out and placed in individual vials for emergence. Some of the bands were exposed, collected, and sent to Moorestown by cooperating State workers. The greater part of the banding was done between June and September.

From 1931 to 1935, inclusive, cocoons produced in the insectary were also exposed to parasite attack in orchards in the vicinity of Moorestown. The cocoons were exposed in lots of 25 or more by pinning one or two cocoons in cardboard corrugations to the trunks of the trees. The cocoons were exposed in the orchards from 3 to 8 days. They were then removed and isolated for insect emergence. Soon after the exposure of one lot of cocoons another lot was placed in the orchard. In 1931, 19 lots were exposed in one orchard from June 4 to October 1; in 1932, 24 lots in each of two orchards from April 1 to October 29; in 1933, 11 lots in each of four orchards from April 5 to July 15; in 1934, 19 lots in each of six orchards from May 7 to September 18; and in 1935, 20 lots in each of four orchards from April 5 to August 28.

In 1940 and 1945 the cocoons used for exposure during the first brood of the oriental fruit moth were obtained from larvae in infested peach twigs collected in the various orchards in which cocoons were to be exposed. During the second brood in 1940 only insectary-reared cocoons were exposed in the orchards, while in 1945 about half of the cocoons exposed were obtained from larvae in infested peach twigs and half were reared in the insectary. In 1940, cocoons were placed in four orchards on June 14 (first brood) and in eight orchards on July 5 and 8 (second brood). In 1945 cocoons were placed in five orchards on June 16 (first brood) and in five orchards on July 21 and 23 (second brood). One cocoon in a cardboard corrugation was pinned to the trunk of the tree and one on each major limb about half way from the trunk to the first lateral branch. The trees on which cocoons were placed were five trees apart. The number of cocoons placed in each

[1] Earl Lott, G. J. Haeussler, W. P. Yetter, Jr., and several temporary assistants also participated in the work on which this article is based.

orchard during each exposure period ranged from 100 to 250. The cocoons were allowed to remain on the trees for 11 days, after which they were removed to the insectary and isolated for emergence.

All cocoons were held for emergence at normal temperature until late fall of each year. Those from which no emergence had occurred were wintered in a cold chamber at 42° F. until spring of the following year, when they were subjected to normal temperature again until fall for further emergence. The remaining cocoons were then examined for dead insects. In the cocoons formed in trap bands on trees in 9 counties in 2 States in 1931, and in 26 counties in 8 States in 1932. A total of 11 species of primary cocoon parasites were reared. Parasitized cocoons were obtained from nearly all the counties in which observations were made. The highest degrees of parasitization were 42 per cent in Monmouth County, New Jersey, in 1931 and 51 per cent in Botetourt County, Virginia, in 1932. The parasitization in individual orchards frequently approached 100 per cent. The records obtained for all species that parasitized 1 per cent or more

Table 1.—Parasitization of the oriental fruit moth in cocoons formed in trap bands on peach trees, 1931 and 1932.

Year and State	Number of Counties	Total Number of Insects Emerging	Percentage Parasitization by Species							
			Dibrachys cavus (Walk.)	*Eupelmus spongipartus* Foerst.	*Eurytoma appendigaster* (Swed.)	*Gambrus ultimus* (Cress.)	*Habrichella xanticles* (Walk.)	*Mastrus pilifrons* (Prov.)	All Others	Total
1931										
New Jersey	7	252	14.3	—	2.8	—	—	0.4	2.4	19.9
Pennsylvania	2	203	27.1	—	—	—	—	1.0	0.5	28.6
1932										
Connecticut	1	151	9.9	0.7	1.3	2.0	—	1.3	2.6	17.8
Maryland	2	79	3.8	1.3	—	—	—	15.2	3.8	24.1
Massachusetts	1	101	7.9	—	4.0	3.0	—	3.0	10.9	28.8
New Jersey	2	1294	0.7	0.1	—	2.8	—	0.9	1.0	5.5
New York	4	237	1.3	8.9	11.4	—	—	2.1	3.8	27.5
Ohio	6	138	13.7	2.2	2.9	—	—	2.2	5.8	26.8
Pennsylvania	4	100	4.0	4.0	—	1.0	—	7.0	2.0	18.0
Virginia	6	84	4.8	—	—	—	25.0	2.4	2.4	34.6
Total or weighted average	35	2639	5.9	1.2	1.7	1.6	0.8	1.8	2.2	15.3

conduct of the field work some cocoons were lost, and some prepupae and pupae were killed by predators or died for unknown reasons. These data are based, therefore, on those cocoons from which emergence was obtained. The percentage of cocoon parasitization is based on total insect emergence. The percentage of secondary parasitization is based on total parasite emergence.

The identifications of nearly all the parasite species reared in these studies were either made or verified by members of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine.

COCOONS IN TRAP BANDS.—Data were obtained in 1931 and 1932 from 2639 of the cocoons obtained from at least one State are summarized in table 1. Other primary parasites that were reared in smaller numbers were as follows: *Calliephialtes variatipes* (Prov.), *Coccygomimus inflatus* (Townes), *Encyrtaspis semirufus* Gahan, *Itoplectis conquisitor* (Say.), and *Nemorilla floralis* (Fall.).

EXPOSURE OF INSECTARY-REARED COCOONS.—Eighteen species of primary cocoon parasites were reared in New Jersey from insectary-reared cocoons exposed in orchards near Moorestown. Species that parasitized 1 per cent or more of the cocoons exposed in any one year are presented in table 2. Other species that were reared were *Arachnophaga frontalis* Gah., *Scambus hispae* (Harris),

Eupelmus cyaniceps v. *amicus* Gir., *Eupelmus limneriae* How., *Haltichella xanticles* (Walk.), *Gambrus ultimus* (Cress.), and *Syntomosphyrum esurus* (Riley).

The high degree of parasitization obtained in 1940 and 1945 might have resulted, in part, from the exposure of cocoons to parasite attack for 11 days instead of for 3 to 8 days as in previous years. In 1931, however, cocoons were exposed for periods ranging from three to five days. The low degree of parasitization obtained from second brood cocoons exposed in 1945 may have been due to bad weather conditions during the exposure period. The percentage of cocoons parasitized usually varied considerably in different orchards each year. Parasitization ranged in 1933 from 6.0 to 42.8 per cent, in 1934 from 1.8 to 26.0 per cent, in 1935 from 0.7 to 27.5 per cent, in 1940 during the first brood from 17.9 to 50.6 per cent and, during the second brood from 3.7 to 79.0 per cent, and in 1945 during the first brood from 17.5 to 46.8 per cent and during the second brood from 1.2 to 8.6 per cent.

It may be seen upon examining table 2 that most of the species of parasites were reared each year in varying relative abundance. Occasionally certain species were reared in great abundance from one orchard. Two species exemplify these peculiarities. *Phaeogenes walshiae* was reared in abundance in 1931, but was reared in small numbers only during the succeeding years until the first brood in 1940, when it parasitized 8.0 per cent of all the cocoons exposed and 24.1 per cent of the cocoons exposed in one orchard. Although the same orchards were under observation in 1945, it was not recovered during the first brood. *Itoplectis conquisitor* also was reared in abundance in 1931. It was of little or no importance in other years with one exception. During the second brood in 1940, when it was reared from only one orchard, it parasitized 43.5 per cent of the cocoons exposed.

Table 2.—Parasitization of oriental fruit moth in insectary-reared cocoons exposed near Moorestown, N. J., 1931 to 1935, 1940, and 1945.

Year	Number of Orchards	Total Number of Insects Emerging	Percentage Parasitization by Species												
			Calliephialtes graphiticae (Cress.)	*Coccygominus inflatus* (Townes)	*Dibrachys cavus* (Walk.)	*Encyrtarpis semirufus* Gah.	*Eupelmus spongiparius* Foerst.	*Eurytoma appendigaster* (Swed.)	*Gelis tenellus* (Say)	*Itoplectes conquisitor* (Say)	*Lymeon orbus* (Say)	*Mastrus pilifrons* (Prov.)	*Phaeogenes walshiae* Ashm.	All others	Total
1931	1	2170	1.0	—	0.8	—	—	2.4	0.5	6.3	0.6	2.3	7.1	1.3	22.3
1932	2	1784	—	0.6	1.3	—	0.1	0.6	2.2	0.1	0.2	1.2	0.6	2.7	9.6
1933	4	797	0.1	3.1	1.6	0.1	1.5	3.3	1.8	0.3	0.1	1.5	1.5	0.8	15.7
1934	6	1767	—	5.4	1.0	—	0.7	1.1	0.8	—	0.5	0.8	0.4	2.2	12.9
1935	7	1197	—	3.3	0.5	—	0.1	3.3	2.7	—	0.6	1.3	0.5	1.8	14.1
1940															
First brood	4	536	—	2.4	1.1	1.1	—	1.5	0.4	—	1.5	1.5	8.0	3.0	20.5
Second brood	8	570	—	2.3	1.2	0.4	1.6	4.6	0.7	4.7	0.9	0.9	1.1	0.9	19.3
1945															
First brood	5	455	—	0.7	4.8	—	2.0	17.4	0.2	—	—	1.1	—	1.1	27.3
Second brood	5	856	—	0.6	1.2	—	—	1.8	—	—	0.2	1.3	0.6	0.1	5.8
Total or weighted average	42	10,132	0.2	2.0	1.2	0.1	0.4	2.7	1.2	1.7	0.5	1.4	2.4	1.7	15.5

SECONDARY PARASITES.—In the course of these observations data were obtained which showed that many of the primary cocoon parasites were also secondary parasites through oriental fruit moth larval parasites and other cocoon parasites. These data were primarily on the larval parasites, as the cocoons were usually removed from the orchards before the cocoon parasites reached advanced stages of maturity. The species of parasites and the number of times they were reared as primary and as secondary parasites are given in table 3. The data show that the majority of the species were secondary parasites more frequently than primary parasites. The cocoons exposed in 1940 and 1945 were formed by field-collected twig larvae that had been parasitized prior to collection to the degree of 33 per cent and 57 per cent, respectively. In view

of these facts the data obtained during these two years suggest that some species, notably *Arachnophaga frontalis, Eupelmus spongipartus, Dibrachys cavus, Gelis tenellus,* and *Eurytoma appendogaster,* searched out parasites for attack, as these five species were reared more than 50 per cent of the time as secondary parasites.

Table 3.—Number of times that species of parasites were reared as primary and as secondary parasites during 1932 and during first brood in 1940 and 1945.

Species	Total Number of Times Reared as		Percentage of Times Reared as Secondary Parasite
	Primary Parasite	Secondary Parasite	
Bathythrix peregrina (Cress.)	—	1	100.0
Perilampus fulvicornis Ashm.	—	1	100.0
Eupelmus allynii (French)	—	3	100.0
Eupelmella vesicularis (Retz.)	—	5	100.0
Eupelmus cyaniceps v. *amicus* Gir.	—	10	100.0
Arachnophaga frontalis Gah.[1]	3	35	92.1
Eupelmus spongipartus Foerst.	10	57	85.1
Dibrachys cavus (Walk.)	57	138	70.8
Gelis tenellus (Say)	4	9	69.2
Eurytoma appendigaster (Swede.)	90	132	59.5
Encyrtaspis semirufus Gah.	8	2	20.0
Lymeon orbus (Say)	8	1	11.1
Coccygomimus inflatus (Townes)	21	2	8.7
Mastrus pilifrons (Prov.)	53	2	3.6

[1] Although this species was not described until 1943 (Gahan 1943) all specimens of *Arachnophaga* reared in 1932 and 1940 were sent to the Division of Insect Identification and were later identified by Gahan as *A. frontalis.*

Secondary parasitization occurred generally in all the States where observations were made. In 1932, 32 per cent of the parasites in cocoons exposed in eight States were parasitized by secondaries. In 1940 the highest secondary parasitization recorded in four orchards in New Jersey was 68 per cent, the lowest 45 per cent, and the average 59 per cent. In 1945 the highest recorded in five orchards in New Jersey was 100 per cent, the lowest 58 per cent, and the average 76 per cent.

DISCUSSION.—Although these observations were restricted to cocoons exposed on trees, the results are highly indicative of the benefits derived from cocoon parasites. The relative effectiveness of cocoon and larval parasites is demonstrated by the figures shown in table 4.

In midsummer, particularly in southern New Jersey, the percentage parasitized by cocoon parasites would be lower than

Table 4.—Relative effectiveness of parasites

Time	Total Per Cent Parasitization	Per Cent Caused by—	
		Larval Parasites	Cocoon Parasites
1931 and 1932, late summer	31.7	15.4	16.3
1940, first brood	53.2	20.5	32.7
1945, first brood	84.0	27.3	56.7

shown above, as it is not unusual for 80 to 90 per cent of the larvae feeding in twigs at that time to be parasitized.

Table 1 shows that cocoon parasitization was about the same in all States in which observations were made. It is indicated that cocoon parasites occur generally over the area in which the oriental fruit moth is found, and that many of the species reared are widely distributed. It is shown that a high degree of parasitization by one species was unusual, but that the aggregate parasitization by all species was of considerable importance. Table 2 shows that the degree of parasitization is fairly constant from year to year. Cocoon parasitization is probably considerably higher in nature than that recorded in these observations, as such cocoons are subjected to parasite attack over a longer period of time than were the cocoons from which records were obtained.

SUMMARY.—Observations on the parasitization of oriental fruit moth cocoons on peach trees were made intermittently during seven years between 1931 and 1945. Although most of the observations were made in New Jersey, records were obtained from one other State in 1931 and seven other States in 1932. Records were obtained from 2639 cocoons in trap bands and from 10,132 insectary-reared cocoons exposed on trees. The parasitization of cocoons in trap bands was 15.3 per cent and of exposed insectary-reared cocoons, 15.5 per cent. The degree of cocoon parasitization was relatively high in many orchards and was an important adjunct to larval parasitization in reducing the oriental fruit moth population.

In all, 20 species of primary cocoon parasites were reared. Some of the species of cocoon parasites were also reared as secondary parasites through larval parasites and other cocoon parasites.

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Plum Curculio on Peaches and Plums in Ohio

R. B. NEISWANDER

In the early history of horticulture in Ohio, the plum curculio, *Conotrachelus nenuphar* Herbst., is recorded as one of the most troublesome fruit insect pests in the State. Many ingenious control measures were tried, but none proved very successful until the arsenicals became available. In 1888 Clarence Weed of the Ohio Agricultural Experiment Station began curculio control experiments and in 1890 Weed (1888, 1890) reported on work in which paris green produced good results. Arsenicals were used extensively in succeeding years and the curculio became less troublesome.

In more recent years, however, the curculio has again caused commercial damage. One application of a spray containing lead arsenate has not always resulted in satisfactory curculio control, and on peaches two or three applications sometimes cause arsenical injury.

BIOLOGY.—Studies of the biology of the curculio under northern Ohio conditions were made during each of the past six seasons. The emergence of adults from hibernation and the fluctuation of the adult population through the season were studied by jarring approximately 30 trees at weekly intervals. For this operation a white cloth 10 feet square was spread under a tree and each branch jarred vigorously in order to dislodge the beetles.

The period when beetles first appear on the trees in the spring varies greatly from year to year. In 1945 beetles were jarred from plum trees in Ottawa County as early as April 19, whereas in 1940 none were found until June 1. Beetles can usually be found on peach or plum trees 3 or 4 days after petal-fall, and the period of greatest abundance usually occurs during the 2 weeks following petal-fall. However, cold weather at that time may delay the emergence of the adults from hibernation and prolong the egg laying period. During one of the past 6 seasons the peak of curculio activity occurred 1 week after petal-fall, but in another it occurred 6 weeks after petal-fall.

The larval population was studied during the same six seasons by rearing the larvae from drop fruits. Inasmuch as practically all infested fruits of the mid-season varieties of peaches and plums drop to the ground before reaching maturity, a measure of the population on a tree was obtained by rearing the larvae from drops collected at intervals of 3 or 4 days during the entire period that infested fruits were falling. During the seasons of 1945, 1946, and 1947 all of the trees in a block of 117 Stanley prunes and another of 125 Zarn peaches in Ottawa County, Ohio, were studied in this manner.

The drop fruits were taken to the insectary at Wooster and placed in onion bags suspended over 12-quart pails. As the larvae emerged from the fruits they dropped into the pail and were collected and counted each day.

The period in which larvae were emerging during the 3 seasons is shown graphically in figure 1. Emergence began approximately 10 days later in 1947 than in either of the 2 previous seasons, but the

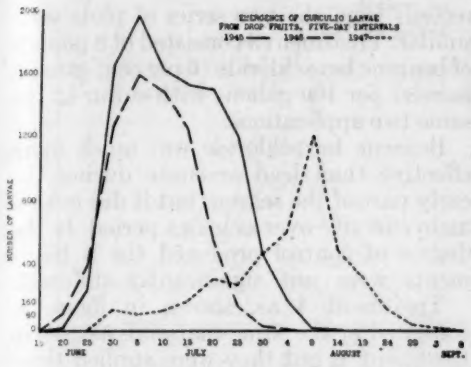

FIG. 1.—Periods of emergence of curculio larvae from fruits that dropped from 117 plum and 125 peach trees.

peak occurred more than a month later. Although the population in 1947 was lighter than in either of the 2 previous seasons, control was more difficult, especially on plums, because the larvae continued to feed over a much longer period. The increase in the length of the feeding period in 1947 was correlated with an excess of rainfall during April, May and June. Official weather records show a state average for the 3 months in 1947 of 16.68 inches as compared with a general average for the period of 10.95 inches.

In order to obtain a record of the period of emergence of the adults, the larvae obtained from the pails in the manner described above, were placed in cages where they were permitted to enter the soil and complete their development. As the adults emerged they were removed and the number recorded each day.

The period of summer adult emergence during the 3 seasons of 1945, 1946, and 1947 is shown graphically in figure 2. This period was also later and continued longer in 1947 than in either of the 2 previous seasons. The marked drop in emergence that occurred during midseason in both 1945 and 1946 corresponds in each case with a period of dry weather. Immediately followed a rain, large numbers of adults again emerged.

Only one brood of curculio larvae is known to occur annually in Ohio. Numerous attempts have been made to obtain second brood eggs in cages. Frequently the first beetles of the new brood were placed in cages with peaches, plums, or apples, but no curculio eggs or larvae were obtained.

It is evident from the biological records that have been accumulated that the length of the egg laying period, the length of the period in which larvae are feeding, and the number of larvae that complete their development and emerge as adults vary greatly from season to season because of variable weather conditions.

CONTROL INVESTIGATIONS.—Studies in control of the plum curculio have been carried on at the Ohio Agricultural Experiment Station during six consecutive

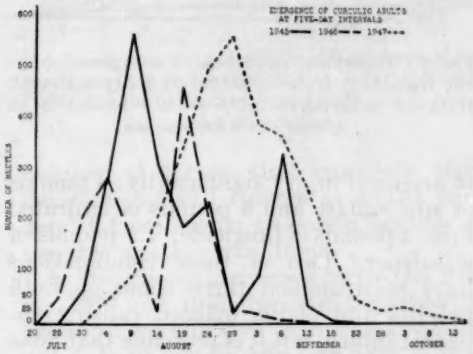

FIG. 2.—Emergence periods for curculio adults reared from larvae in fruits that dropped from 117, plum and 125 peach trees.

seasons. The chief objective during this period has been to find a substitute for acid lead arsenate in the peach spray program or to find a safener that would permit the application of three lead arsenate sprays on peach foliage without causing injury.

Sprays containing fluorine were tested in 1943. However, the fluorine sprays caused more foliage injury than acid lead arsenate and were less effective in reducing the curculio population (Neiswander 1944).

Basic lead arsenate was tested six times during a period of 3 seasons and was used both with and without hydrated lime. When used at a concentration sufficient to equal the effectiveness of acid lead arsenate it seemed no safer on peach foliage than the acid form.

Acid lead arsenate was used at 2 and at 3 pounds in 100 galllns of water and in from one to three applications. The degree of control obtained varied directly with the amount of lead arsenate applied. The following compounds, when used with 2 pounds of acid lead arsenate in 100 gallons of water, seemed to reduce the hazard

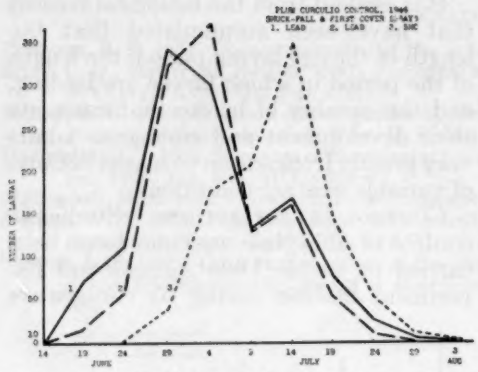

FIG. 3.—Period and magnitude of emergence of larvae from drop fruits collected at 5-day intervals. Data for each curve taken from 4 replicates on plums and 4 on peaches.

of arsenical injury significantly: 4 pounds of zinc sulfate and 6 pounds of hydrated lime; 2 pounds of fungicide;[1] 1.5 pounds of a safener.[2] Two of these combinations have been applied three times on both peaches and plums without causing apparent injury, but it is probable that none of them completely eliminates the injury hazard.

Benzene hexachloride was used in 1946 and 1947. During both seasons experimental spray schedules were tested on both peaches and plums. Plots consisted of 4 trees arranged in a square, and each treatment was replicated 4 times on peaches and 4 times on plums. The varieties represented were chiefly Stanley prunes and Zarn peaches.

In 1946 the applications were designated as petal-fall, shuck-fall, and first cover, and were applied respectively on May 5, May 20, and May 31. A measure of the curculio population in each plot was obtained by rearing the larvae from the drop fruits collected at 3 or 4 day intervals. The total number of larvae emerging from the fruits collected in the eight plots (peaches and plums) that received a given treatment are shown graphically in figures 3 and 4.

As indicated in figure 3, treatments 1 and 2 included 2 pounds of acid lead arsenate in 100 gallons in the shuck-fall and first-cover sprays. The difference between the two treatments consisted in the fungicide and safener used. The emergency records from the two series of plots were similar. Treatment 3 consisted of 3 pounds of benzene hexachloride (6 per cent gamma isomer) per 100 gallons with sulfur in the same two applications.

Benzene hexachloride was much more effective than lead arsenate during the early part of the season, but it did not remain effective over as long a period. In the degree of control produced the 3 treatments were not significantly different.

Treatment 4 as, shown in figure 4, consisted of the same materials as used in treatment 1, but they were applied three times instead of two. Treatment 5 consisted of 3 applications of benzene hexachloride. Both graphs indicate that in 1946 the petal fall spray reduced the curculio population significantly. Figure 4 again shows benzene hexachloride to be more effective than lead arsenate during the early part of the season, but less effective later.

The data obtained in 1947 are shown graphically in figures 5 and 6. The treatments represented in figure 5 were a duplication of those shown for the previous year in figure 4. However, larvae continued to feed in plums for a much longer period in 1947 than in the previous year. The petal fall spray was much less effective in 1947 although the three treatments again rank in the same order. Benzene hexachloride was again more effective than lead during the early part of the season.

As shown in figure 6, treatment 2 in 1947 consisted of 3 applications of benzene hexachloride at 10-day intervals, beginning at shuck-fall. Treatment 3 consisted

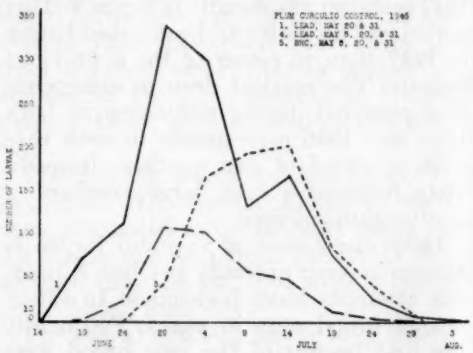

FIG. 4.—Period and magnitude of emergence of larvae from drop fruits collected at 5-day intervals. Data for each curve taken from 4 replicates on plums and 4 on peaches.

[1] Ferric dimethyldithiocarbamate, produced by the E. I. du Pont de Nemours & Co. (Inc.)

[2] *Delmo-Z.* A zinc compound produced by the California Spray-Chemical Corp. (1945 and 1946) as a safener for lead arsenate.

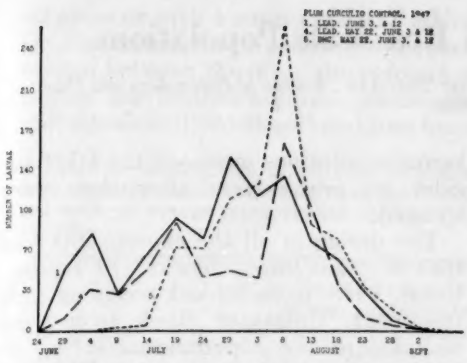

FIG. 5.—Period and magnitude of larvae emergence from drop fruits collected at 5-day intervals. Data for each curve taken from 4 replicates on plums and 4 on peaches.

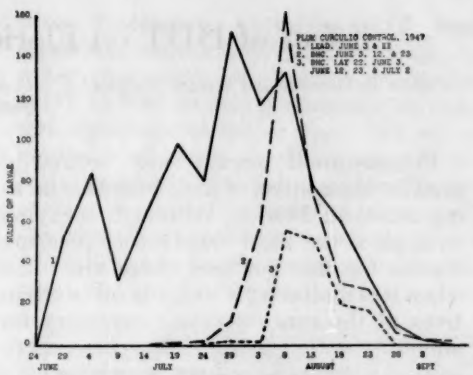
PLUM CURCULIO CONTROL, 1947
1. LEAD. JUNE 3 & 12
2. DNC. JUNE 5, 12, & 23
3. DNC. MAY 22, JUNE 2, JUNE 12, 23, & JULY 2
NUMBER OF LARVAE
JUNE
JULY
AUGUST
SEPT

FIG. 6.—Period and magnitude of emergence of larvae from drop fruits collected at 5-day intervals. Data for each curve taken from 4 replicates on plums and 4 on peaches.

of 5 applications of benzene hexachloride at 10-day intervals beginning at petal-fall. Both were significantly more effective than treatment 1. Also both were very effective during the early part of the season. The total number of larvae obtained from the peaches and plums that received the three treatments were respectively 1006, 378, and 151. Schedules 2 and 3 were even more effective on peaches than on plums. The number of larvae obtained from peaches that received the three treatments were respectively 103, 4, and 1. In order to realize the significance of these figures, it must be borne in mind that treatment 1 (Fig. 6) represents approximately the standard spray schedule for plums in Ohio, and includes one more lead arsenate spray than is usually recommended for peaches.

No treatment injury was observed on any of the experimental plots, and no effect on the flavor of either peaches or plums could be detected as a result of the benzene hexachloride sprays.

CONCLUSIONS.—The length of the curculio egg laying period, the length of the period in which larvae feed, and the number of larvae that complete their development and emerge as adults vary greatly from season to season because of variable weather conditions.

In spraying experiments carried on during 1946 and 1947, benzene hexachloride proved more effective than lead arsenate, but did not remain effective over as long a period.

Benzene hexachloride used in five applications at 10-day intervals beginning at petal-fall caused no foliage injury on peaches or plums, and caused no deleterious flavor in the fruit. It seems to be a satisfactory and effective substitute for lead arsenate in the peach spraying schedule, although one or two additional applications may be necessary.

Because of the possible incompatibility of lime and benzene hexachloride, the use of the latter material on plums may be questionable if fixed copper and lime are needed for the control of leaf spot. However, since lead arsenate causes less damage on plums than on peaches, the need for a lead substitute on plums is less acute.—1-8-48.

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Effect of DDT on Florida Red Scale Populations

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Petroleum-oil sprays are ordinarily used for the control of scale insects attacking citrus in Florida. Although spraying with oil is the most satisfactory measure known for this purpose, there are times when it is undesirable to apply oil to citrus trees at the concentrations necessary for adequate scale control. For years experimental workers have been searching for a substitute for oil, or for a satisfactory toxicant which might be combined with oil to increase its efficiency or to allow for a reduction in the concentration of the oil without decreasing its effectiveness.

A report by Lindgren & Boyce (1944) on the satisfactory effect of DDT for the control of the California red scale, *Aonidiella aurantii* (Mask.), indicated that this material might be combined effectively with oil for the control of the Florida red scale, *Chrysomphalus aonidum* (L.). From 1944 to 1947 three series of experiments were conducted in St. Lucie County, Fla., in which DDT sprays, formulated in various ways, were tested on orange trees for the control of this insect.

MATERIALS AND METHODS.—In 1944 technical DDT was dissolved in an emulsive oil,[3] and diluted with water to form emulsions of two oil concentrations. These sprays were compared with emulsions containing the same concentrations of oil without DDT. In 1945 technical DDT was dissolved in No. 2 fuel oil and emulsified, and a wettable powder containing 50 per cent of DDT was used alone, with fuel oil No. 2 plus an emulsifier, and with an emulsive oil. All the treatments were compared with emulsions containing the two oils without DDT. In 1946 emulsions were made from technical DDT dissolved in No. 2 fuel oil, in No. 2 fuel oil plus aluminum stearate, in xylene, and in xylene plus aluminum stearate. Aluminum stearate was added to two of the formulations, because Ebeling (1945) reported that the addition of this material to DDT-kerosene solutions increased the DDT residue on citrus trees after they were sprayed.

The design in all the experiments was that of randomized blocks (10 replications), 1 tree in each block receiving each treatment. Untreated check trees were included in the experimental set-up in 1944 and 1946, but not in 1945. Different blocks of trees were used for each series of experiments, and the number of trees in each block varied with the number of treatments. The treatments were applied with a power sprayer having a single-nozzle gun equipped with a 0.11-inch disk.

In each experiment the data for comparison of the various treatments were taken from 20 leaves picked at random from each of the 10 trees in each treatment. All the living third-stage female scales were recorded from one half of the upper and one half of the lower surface of each leaf, according to a method described by Osburn & Mathis (1944). Data were taken on the third-stage females because, even though it is known that spray residues containing DDT will kill large numbers of young, crawling Florida red scales for several weeks after trees have been sprayed, the effect of the residues on scale build-up or reinfestation is the test of their efficiency as a control measure. The data were analyzed statistically to determine the significance of differences betweeen treatments.

RESULTS.—Results of the treatments are summarized in tables 1, 2, and 3.

In 1944, when data were taken on July 15, one month after the sprays had been applied, there were no significant differences between the infestations found on any of the treated leaf samples. However, significantly fewer scales were found on each of the treated samples than on the untreated check trees. Even though the differences between treatments were not significant, fewer scales were found on the samples sprayed with DDT and oil than on the samples sprayed with oil alone. The spray containing 1.75 gallons of oil alone was slightly more effective than the sprays containing 1 gallon of

[1] Now with U. S. Public Health Service.

[2] Minter DuPree and Nathan Stahler, formerly of this Bureau, assisted in this work during 1944 and 1945, respectively.

[3] A commercial oil commonly used on citrus in Florida for scale-insect control.

oil alone or with 4 ounces of DDT added. On September 9 no significant differences existed between the infestations found on any of the treated samples, which were still significantly smaller than those found on the check. However, from July 15 to September 9, while the population in the check was decreasing, the infestations on the trees treated with DDT in oil increased faster than those on the trees treated with oil alone. The fewest scales were found on samples sprayed with 1.75 gallons of oil without DDT.

Table 1.—Comparison of DDT-oil emulsions with oil emulsions alone for control of the Florida red scale on orange trees. Sprays applied June 15, 1944.

Treatment (Quantities per 100 Gal. of Water)	Mean Number of Living Third-Stage Females per Whole Leaf on—	
	July 15	September 9
Technical DDT:		
4 oz.+emulsive oil 1 gal.	0.16	0.44
7 oz.+emulsive oil 1.75 gal.	.02	.18
Emulsive oil alone:		
1 gal.	.20	.28
1.75 gal.	.04	.08
Check (untreated)	5.16	3.34
Differences required for significance of the 5 per cent level	2.38	1.00

Table 2.—Comparison of DDT, DDT-oil, and oil treatments for control of the Florida red scale on orange trees. Trees sprayed on Aug. 22, 1945.

Treatment (Quantities per 100 Gal. of Water)	Mean Number of Living Third-Stage Females per Whole Leaf on—	
	Sept. 17	Nov. 15
Technical DDT 3 lb.+fuel oil[1]	0.38	3.72
Wettable DDT 6 lb.:		
Alone	8.92	35.20
Plus fuel oil 3 gal.	.38	3.72
Plus emulsive oil 1.5 gal.	.14	2.06
Fuel oil alone 3 gal.	1.06	2.54
Emulsive oil alone 1.5 gal.	.12	1.02
Differences required for significance at 5 per cent level	1.02	8.58

[1] Fuel oil in all sprays made emulsifiable by adding glycery oleate at the rate of 38 ml. per gallon.

after treatment, wettable DDT used alone was significantly inferior to all the other treatments. Wettable or technical DDT in fuel oil and in emulsive oil were not significantly better than fuel oil or emulsive oil alone. By November 15 infestations had increased in all treatments and the wettable DDT used alone was still the least effective, 35 times as many scales being found on leaves receiving this treatment as on those sprayed with oil alone (the standard scale remedy). Emulsive oil alone was more effective in preventing reinfestation than any of the other treatments, although the differences between it and any other treatment except the wettable DDT did not reach the point of statistical significance.

Table 3.—Comparison of DDT emulsions, with and without aluminum stearate, for control of the Florida red scale on orange trees. Trees sprayed on April 18, 1946.

Treatment (Quantities per 100 Gal. of Water)	Mean Number of Living Third-Stage Females per Whole Leaf on—		
	June 18	July 12	Feb. 5[1]
Technical DDT 3 lb. plus:			
Fuel oil[2] 3 gal.	0.44	3.24	1.86
Fuel oil 3 gal. and aluminum stearate 4 oz.	.74	5.38	—
Xylene[2] 5 pt.	2.00	7.94	1.78
Xylene 3 gal.[3] and aluminum stearate 4 oz.	1.30	9.32	—
Check (untreated)	6.78	—	.46
Differences required for significance at the 5 per cent level	2.10	4.44	1.14

[1] Following two oil sprays, applied July and November 1946.
[2] The fuel oil and xylene were made emulsifiable by adding a phthalic glyceryl alkyd resin to each material at the rate of 38 ml. per gallon.
[3] This amount was necessary for a satisfactory spray mixture when aluminum stearate was added.

In 1946 leaf samples were taken on June 18, and on July 12 samples were taken from all the trees except the checks, which had been sprayed with oil on July 2 to prevent excessive scale insect damage. On July 17 all the treated trees were sprayed with oil for the same reason, and on November 20 all the treated and check trees were again sprayed with oil. In February 1947, three months after the last oil treatment was applied, leaf samples were examined from two of the treatments and the check.

In June, two months after the sprays

were applied, all the treatments were significantly better than the check. However, the differences between treatments were not significant. The addition of aluminum stearate to the formulations did not increase their efficiency. In July the DDT-fuel oil emulsion was significantly more effective than the DDT-xylene emulsion, with or without aluminum stearate; it was not significantly better than the DDT-fuel oil emulsion containing aluminum stearate, but there was evidence that the addition of this material to either emulsion caused an increase in scale infestations. In February 1947, following the two oil treatments in 1946 to all trees, including the check, significantly more living female scales were found on leaf samples from the DDT treatments than were recorded from samples which had received no DDT.

DISCUSSION.—In 1944 and 1945 the experimental applications were made in June and August, respectively, when there was considerable crawler activity, and in 1946 the treatments were applied in April, just prior to the first peak emergence of crawlers for the season. Since the DDT residues are effective in killing scale crawlers for several weeks after application, it is difficult to explain why the DDT treatments did not affect subsequent infestations of mature scales adversely after short periods of time. Instead of a decrease in populations from these treatments there was an increase. In general, populations increased to a greater extent when DDT was used in fuel oil and in xylene than when it was used in emulsive oil, although the concentrations of DDT used in the fuel oil and xylene emulsions were much higher than in those containing emulsive oils. Apparently the type of oil in the last combinations suppressed infestations to a greater extent than did the fuel oil or xylene. Populations increased much more when wettable DDT (50 per cent) was used alone than they did after any other treatment. After a suspension of wettable DDT was applied, quantities of residue, a large proportion of which was insecticidally inert, remained on the trees for a long time. Spray residues containing large amounts of this type of material favor build-up in Florida (Osburn & Spencer, 1938). In addition to the residue factor involved in the wettable-DDT treatment, some of the scale increases associated with all the DDT treatments can be attributed to the destruction of scale parasites and predators by the DDT. According to Griffiths & Stearns (1947) and Griffiths & Thompson (1947), predaceous ladybeetles and hymenopterous parasites of the Florida red scale were virtually eliminated by DDT applications for six weeks or longer.

SUMMARY.—Results of three field experiments conducted in St. Lucie County, Fla., during 1944–47 showed that sprays containing DDT were not satisfactory in reducing infestations of the Florida red scale, *Chrysomphalus aonidum* (L.). In fact, scale population increased abnormally following the use of this material. Increases were greater after applications of a suspension of wettable DDT than after spraying with either oil or xylene containing DDT; they were less after spraying with an emulsive oil containing DDT than after any other DDT treatment. The emulsive oil alone at 1, 1.5, or 1.75 per cent prevented reinfestation better than any other treatment.

Some of the scale increases associated with all the DDT treatments are attributed to the absence of scale parasites and predators, which were destroyed by the DDT, The abnormally high populations associated with wettable DDT used alone were influenced by an additional factor—the presence of large quantities of inert residue which remained on sprayed trees for a considerable length of time.

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Natural-Control Factors Affecting the Spruce Budworm

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Periodically, the spruce budworm, *Archips fumiferana* (Clem.), has caused widespread destruction of balsam fir and spruce in Canada, the northeastern part of the United States, and the Lake States. In Canada, one of the most severe outbreaks on record is now under way (1947), and in Ontario there has been a tremendous loss of timber over more than 20,000 square miles. The insect is also present in outbreak form in the Rocky Mountain region, where Douglas fir is the principal species attacked.

In 1945 a heavy infestation broke out in the Adirondacks, in New York, and the Bureau of Entomology and Plant Quarantine initiated an intensive study program on various phases of the budworm problem, including the natural-control factors. It is hoped that this study may lead to an evaluation of the effect of natural control on the periodicity of outbreaks; also that certain factors, such as beneficial parasites that occur in some infested areas, may be successfully introduced into other localities. The object of this preliminary report is to record the natural-control factors operating against the pest and to outline the work that has been done to date in that field.

THE ROLE OF NATURAL-CONTROL FACTORS.—Obviously, natural-control factors fail periodically to prevent the budworm from increasing to outbreak proportions. Tothill (1923), Graham & Orr (1940), and Keen (1939) concluded that the natural-control factors, which are ineffectual during the early part of an outbreak, become of considerable importance toward the end, after a high proportion of the host larvae have died from starvation, owing to the depletion of their food supply. In a general way this conclusion may be justified, but in order to recommend a satisfactory control program, it is important to understand more fully the role these natural-control factors play, not only during an outbreak but also between outreaks, particularly in areas where a considerable proportion of the trees survive a heavy infestation.

PARASITES.—Parasites are often important natural-control factors, and their value is of special interest, because frequently certain species can be established in an area where they are not present. Very little has been published on spruce budworm parasites, therefore one of the first steps in this study has been the compilation of parasite records (Tables 1 and 2). The species reared during the course of this study are indicated by the letter "R" in column 2. The species that have not as yet been reared are recorded from the literature. A general idea regarding the abundance of the different species has been indicated by use of the following terms: "Present," known to occur in an area but has not been reared from budworm; "rare," occasionally reared from budworm; "common," reared from budworm in small numbers at most collection points; "abundant," at least 5 per cent of the budworms were parasitized at one collection point. This classification is based on limited information and is only tentative, but it provides a general idea of the relative importance of the species.

REDISTRIBUTION OF PARASITES.—Tothill (1923) recommended the introduction of an important budworm parasite, *Phytodietus fumiferanae* Roh., from British Columbia into eastern Canada. An intensive program to introduce *Phytodietus* as well as other budworm parasites that occur in the West but not in the East, was initiated by Canadian entomologists in 1943. This work has recently been reported by Wilkes (1946). The Bureau of Entomology and Plant Quarantine cooperated in the Canadian program by making some shipments of budworm material from Colorado to the Dominion Parasite Laboratory at Belleville, Ontario. This work showed that most of the species in British Columbia are also present on the eastern slopes of the Rocky Mountains in the United States. During 1946, W. D. Buchanan, of the Fort Collins, Colo., laboratory, carried on rather large-scale rearing of budworm larvae, and obtained several colonies of parasites for shipment east. About 200 cocoons of *Phytodietus*, which spends the winter in this stage, are being held for adult liberation in 1947. Another species not

Table 1.—Primary entomophagous parasites of the spruce budworm in North America. (Original records that have been placed in synonomy are shown in parentheses.)

Species	Reference	Stage of Host Affected		Abundance	
		Attack	Emergence	East	West
Hymenoptera: Ichneumonidae					
Campoplex sp.	Daviault (1946)	Larvae	?	Rare	?
Coccygomimus (=*Ephialtes*) *sanguinipes* (Cress.)	Bedard (1938)	Prepupae and pupae	Pupae	Absent	Rare
Coccygmimus (=*Ephialtes*) *pedalis* (Cress.)	R	Prepupae and pupae	Pupae	Rare	Present
Ephialtes ontario (Cress.)	R	Prepupae and pupae	Pupae	Abundant	Rare
Exochus sp.	R	Larvae	Pupae	Rare[1]	?
Glypta fumiferanae (Vier.)	R	Hibernating larvae	Larvae	Abundant	Abundant
Horogenes cacoeciae (Vier.)	R	Larvae	Larvae	Common[2]	Rare
Itoplectis viduata (Grav.) (=*Itoplectis atrocoxalis* (Cress.))	Bedard (1938)	Prepupae and pupae	Pupae	Absent	Rare
Itoplectis conquisitor (Say)	R	Prepupae and pupae	Pupae	Abundant	Common
Itoplectis obtusus Cush.	R	Prepupae and pupae	Pupae	?	Common[2]
Itoplectis quadricingulatus (Prov.) (=*Itoplectis esuchus* Cush.)	Bedard (1938)	Prepupae and pupae	Pupae	Present	Rare
Phaeogenes hariolus (Cress.) (=*Phygadeuon plesius* Vier.)	R	Prepupae and pupae	Pupae	Rare[2]	Abundant
Phytodictus fumiferanae Roh.	R	Larvae	Larvae	Absent	Abundant
Pimplopterus sp.	Wilkes and Anderson (1947)	?	?	Rare	?
Scambus probably *alboricta* (Cress.)	Wilkes and Anderson (1947)	Larvae	Larvae	Rare	?
Scambus (=*Epiurus*) *atrocoxalis* (Ashm.)	Bedard (1938)	Prepupae and pupae	Pupae	Absent	Rare
Scambus hispae (Harris) (=*Epiurus innominatus* Vier.)	R	Prepupae and pupae	Pupae	Rare	Rare
Scambus sp.	Daviault (1946)	?	?	Rare	?
Hymenoptera: Braconidae					
Apanteles fumiferanae Vier.	R	Hibernating larvae	Larvae	Abundant	Abundant
Ascogaster sp.	Brown (1941)	?	?	?	?
Macrocentrus amicroploides Vier.	R	Larvae	Larvae	Present	Rare
Meteorus trachynotus Vier.	R	Larvae	Larvae	Common[2]	Rare
Meteorus near *trachynotus* Vier.	Wilkes and Anderson (1947)	Larvae	Larvae	Rare	?
Microgaster sp.	Mills (1942)	Larvae	Larvae	?	Rare
Microbracon politiventris (Cush.)	R	Larvae	Larvae	Present	Rare
Rogas sp.	Daviault (1946)	Larvae	Larvae	Rare	?
Hymenoptera: Chalcidoidea					
Copidosoma sp.	Wilkes and Anderson (1947)	?	Larvae	Rare	?
Dicladocerus sp.	R	Larvae	Larvae	Abundant	?
Elachertus sp.	Daviault (1946)	Larvae	Larvae	Rare	?
Encyrtinae	Wilkes and Anderson (1947)	Larvae	Larvae	Rare	?
Trichogramma minutum (Riley)	R	Egg	Egg	Abundant	Common
Diptera: Larvaevoridae					
Actia interrupta Curr. (=*Actia pilipennis* (Fall.) of American authors)	R	Larvae	Larvae	Rare	Rare
Aplomya caesar (Aldr.)	R	Larvae	Larvae and pupae	Abundant	Rare
Ceromasia auricaudata T. T.	R	Larvae	Pupae	Absent	Abundant
Lypha setifacies (West) (=*Lypha dubia* (Fall.) of American authors)	Brown (1941)	Larvae	Larvae	Rare[3]	Rare
Madremeyia saundersii (Will.)	R	Larvae	Larvae and pupae	Rare[2]	Abundant
Maricera rutila (Meig.)	Tothill (1923)	?	?	Rare	?
Nemorilla floralis (Fall.) (=*N. maculosa* Meig. =*N. pyste* Walk.)	Bedard (1938)	Larvae	Pupae	Present	Rare
Phorocera erecta Coq.	Belleville Parasite Lab. (Unpublished	Larvae	Larvae and pupae	Rare	Common
Phorocera incrassata (Smith)	Wilkes (1946)	Larvae	Pupa	?	Rare
Omotoma (*Winthemia*) *fumiferanae* (Toth.)	R	Larvae	Pupae	Common[3]	Abundant
Phryxe pecosensis T. T. (=*Phryxe vulgaris* (Fall.) of Authors)	R	Larvae	Larvae and pupae	Abundant	Rare
Xanthophyto sp.	R	Larvae	Pupae	?	Rare
Diptera: Sarcophagidae					
Agria affinis (Fall.)	Wilkes (1946)	Larvae and pupae	Pupae	Rare	Abundant
Sarcophaga sp.	Brown (1941)	?	?	?	?

[1] Sometimes common in light infestations.
[2] Sometimes abundant in light infestations.
[3] Abundant at some places.

present in the East, *Ceromasia auricaudata* T. T., was also obtained. This is a larvaevorid fly that emerges in the summer. Several good colonies were received and liberated in the Adirondacks (Table 3), and Canadian entomologists supplied

Table 2.—Secondary entomophagus parasites of the spruce budworm in North America. (Original records that have been placed in synonomy are shown in parentheses.)

Species	Reference	Stage of Host Affected		Abundance	
		Attack	Emergence	East	West
Hymenoptera: Ichneumonidae					
Gelis tenellus (Say)	R	Primary parasites	Cocoons of primary	Common	Common
Mesochorus diversicolor Vier.	R	Primary parasites	Cocoons of primary	?	Rare
Hymenoptera: Chalcidoidea					
Amblymerus (=*Nasonia*) *tortricis* (Brues)	R	Primary	Pupae	Abundant	?
Amblymerus verditer (Nort.)	R	Primary Parasites	Pupae	Abundant	Common
Eulophus sp.	Brown (1941)	Primary parasites	?	?	?
Hypopteromalus sp.	Brown (1941)	Primary parasites	?	?	?
Mormoniella sp.	Tothill (1923)	Primary parasites	?	Rare	?

colonies of *Phytodietus*, *Agria affinis* (Fall) *Madremyia saundersii* (Will.), and *Omotoma fumiferanae* (Toth.) for release in New York. The last three species are common in the West but were rare in the Adirondacks in 1946.

Experimental rearing in the East in 1946 indicated that the larvaevorid fly *Compsilura concinnata* (Meig.) will readily attack spruce budworm larvae, and that the larviposited maggots develop to maturity. This species was successfully imported from Europe as a parasite of the gypsy moth and is now common in the Eastern States as a parasite of many lepidopterous larvae. The present writers have plans to rear the species for colonization in Colorado in 1947.

PREDATORS.—A number of species of birds conspicuously prey on the spruce budworm. Tothill (1923) called attention to the importance of birds in New Brunswick and listed the species that prey on the budworm in British Columbia. He credited birds with terminating the British Columbia infestation after a combination of natural-control factors had brought about a reduction in the population of the pest. Graham & Orr (1940) also called attention to the importance of birds, pointing out that, although the inherent population limitation of birds prevents them from increasing enough to check outbreaks, they may be very valuable when the budworm population is low. Those authors suggested that the 1912 outbreak in Minnesota might have been precipitated by the scarcity of small insectivorous birds, notably warblers following severe snow and ice storms late in the springs of 1907 and 1910. Fifteen different species of birds have been observed feeding on the budworm in study plots in the Adiron-

Table 3.—Liberations of spruce budworm parasites in the Adirondacks in 1946.

Species	Locality	Number of Parasites Colonized	Date	Source of Material
			July	
Ceromasia auricaudata T. T.	Hollywood	1020	14	Colorado
	Osgood River	962	15	
	Lake Placid	1000	16	
	Long Lake	951	17	
	Fish Pond	700	19	
	Cross Clearing	466	22	
	Whiteface Mountain	500	8	British Columbia
Madremyia saundersii (Will.)	Hollywood	190	14	Colorado
	Lake Placid	174	16	
	Whiteface Mountain	411	8	British Columbia
Omotoma fumiferana (Toth.)	Whiteface Mountain	66	8	
Agria affinis (Fall.)	Fish Pond	44	24	
			June	
Phytodietus fumiferanae Roh.	Hollywood	347	19	

dacks. George & Mitchell[1] estimated that during 1946 there were three pairs of insectivorous birds per acre in the spruce-fir forests of that region and budworm larvae constituted their chief source of food. An intensive study of the bird populations is proposed for 1947 to estimate the number of budworms destroyed during both heavy and light infestations. No observations have yet been made on the numbers of budworm larvae destroyed by spiders, but Johannsen (1913) and Tothill (1923) indicated that these predators may destroy large numbers of newly hatched larvae before they form their hibernacula.

DISEASE.—During the two seasons this study has been under way, very little mortality of either larvae or pupae of budworms due to disease has been observed. At one study plot in the Adirondacks, where seasonal development was considerably delayed on account of the high elevation, about 30 per cent of the pupae seemed to be affected in 1946. Dr. Kenneth Graham, of the Forest Insect Laboratory at Sault Ste. Marie, Ontario, found that some of these pupae contained the polyhedral bodies characteristic of virus diseases. Mathers (1932) reported that "several as yet undetermined pathological and physiological diseases were effective against the budworm" in the Barkersville district, central British Columbia.

CLIMATE.—Adverse climatic conditions undoubtedly destroy great numbers of budworms. In 1945 late spring frosts killed a high proportion of the new shoots of Douglas fir in Colorado, and of balsam fir and white spruce in eastern Canada. Most of the budworm larvae in the shoots at that time were killed directly by freezing or by destruction of their favored food. No important reductions in budworm populations because of adverse weather were observed in 1946.

EVALUATION OF NATURAL-CONTROL FACTORS.—It is much too early to attempt to evaluate the effect of natural-control factors on budworm populations. Only one full season has been spent in the Adirondacks, and the principal work during two seasons in Colorado has been rearing material to obtain parasites for shipment east. Nevertheless, some rather significant data have been obtained.

[1] Unpublished manuscript.

In the Adirondacks.—The investigations in the Adirondacks are particularly interesting because of the history of the outbreak. The budworm was not discovered there until 1945, but it was then present in epidemic proportions over a wide area. A careful examination of foliage throughout the infested area has shown that there was no noticeable feeding in 1944. The conclusion is that the outbreak arose very suddenly, either from a very sparse, widely dispersed population or from a heavy influx from outside. The latter is at least a possibility, since heavy infestations were raging in Ontario. In any event, these observations have been conducted in relatively "new" infestations. In 1946 eleven study plots which exhibited varying degrees of budworm infestation in the common forest types of the region were established. At each of these plots a collection of overwintering larvae was made, followed by two collections of nearly full-grown larvae, two collections of pupae, and a collection of egg masses. An examination of infested buds at the time the larvae were in about the fourth instar provided data on mortality after the buds were entered and before the larvae were feeding in more open shoots. The small overwintering larvae were dissected for records of parasitization. Some of the large larvae were dissected and some were reared. Records of parasitization are based on dissections. Pupae and egg masses were held in the laboratory for emergence of hosts and parasites.

Two hymenopterous parasites, *Apanteles fumiferanae* Vier. and *Glypta fumiferanae* (Vier.), were abundant in all the study plots. Brown (1946) has given accounts of their biology and detailed descriptions of their developmental stages. Each species is a solitary, internal parasite which overwinters as a first instar within the tiny, hibernating host larva. Combined parasitization by the two species averaged 28 per cent, with a range of 8 to 44 per cent at the 11 plots. *Apanteles* was almost twice as common as *Glypta*. Two species of larvaevorid flies, *Phryxe pecosensis* (T. T.) and *Aplomya caesar* (Ald.), which attack budworm larvae, emerged in considerable numbers from both larvae and pupae collected in all plots. The combined parasitization of larvae by these species ranged from 2 to

38 per cent with an average of 14 per cent, and parasitization of pupae ranged from 1 to 17 per cent, with an average of 7 per cent. Both species are multibrooded, requiring an alternate host for hibernation. Late in July the adult flies were so numerous in the Adirondacks that they were very conspicuous in all the plots. *Phryxe* was generally more common than *Aplomya*. Pupae were rather heavily parasitized by two hymenoptera, *Ephialtes ontario* (Cress.) and *Itoplectis conquisitor* (Say.) These species were heavily attacked in turn by two gregarious chalcidoids, *Amblymerus verditer* (Nort.) and *Amblymerus tortricis* (Brues). Combined parasitization of the pupae by hymenopterous parasites ranged from 14 to 46 per cent, with an average of 28 per cent. *Ephialtes* was generally more abundant than *Itoplectis*. Only one egg parasite, *Trichogramma minutum* (Riley), was recovered. The highest percentage of eggs parasitized at a study plot was 23, the lowest 3. The average parasitization at 11 plots was 12.

In addition to the common species mentioned above, a few specimens of the following primary parasites were obtained at several study plots as follows: Hymenoptera—*Horogenes cacoeciae* (Vier.), *Meteorus trachynotus* Vier., *Dicladocerus* sp., and *Exochus* sp.; Diptera—*Madremyia saundersii* (Will.), *Omotoma fumiferanae* (Toth.), and *Actia interrupta* Curr. In one plot (Whiteface Mountain) 10 per cent of the larvae in one collection were parasitized by *Horogenes*, but the species was rare in the other plots.

Percentages of parasitization were calculated for each collection in the usual manner. It was necessary to adjust these figures for the second larval and second pupal collections, however, because a considerable proportion of the host population had pupated or emerged when these collections were made. The adjustment was made by taking into consideration the proportion of the host population that had thus escaped parasitization by the factors under consideration. Mortalities caused by the various factors at different stages of the insect's development are summarized in table 4. Aggregate per cent mortality represents the real proportion of host population destroyed by all the factors.

Table 4.—Mortality of the spruce budworm from various natural-control factors at 11 collection points in the Adirondacks in 1946.

Collection Point	*Apanteles* and *Glypta* (Hibernating Larvae) (a)	Miscellaneous Predators and Disease (4th Instar) (b)	*Phryxe* and *Horogenes* (1st Larval Coll.) (c)	*Aplomya* (2nd Larval Coll.) (d)	*Phryxe*, *Aplomya*, and *Itoplectis* (1st Pupal Coll. (e)	*Ephialtes* (2nd Pupal Coll.) (f)	*Trichogramma* (Eggs) (g)	Aggregate[1] Per Cent
Long Lake	29	16	4	2	25	10	17	69
Cross Clearing	24	10	10	1	13	14	18	63
Fish Creek Pond	42	8	0	4	11	24	5	67
Hollywood	25	4	2	0	12	21	15	58
Hayes Brook	40	4	24	1	8	33	23	79
Lake Placid	37	7	14	6	4	13	23	70
Whiteface Mountain	32	—	16	5	20	11	—	61
Osgood River								
(Balsam)	44	6	22	3	12	32	9	78
(Black Spruce)	21	10	20	18	20	44	9	81
Fish Pond								
(Balsam)	8	15	5	2	12	16	5	49
(Red Spruce)	16	7	6	1	25	7	3	51
Fishing Brook[2]	34	—	12	4	4	—	—	—
Aiden's Lair[2]	12	—	—	—	—	—	—	—

[1] Aggregate per cent mortality—a+(1−a)b+(1−a) (1−b)c etc. where a, b, c, etc., are percentages attributed to the different control factors.

[2] Impossible to make some collections because infestation was too light.

The percentages of parasitization by *Trichogramma* (Table 4) pertain to the budworm generation that would be feeding in 1947, and their inclusion assumes that egg parasitization was the same in the fall of 1945 as in 1946. No data were available for the fall of 1945, therefore the 1946 percentages were used.

Perhaps the most significant feature of the data in table 3 is the fact that aggregate parasitization at the various plots was generally high, regardless of the density of host population. At Hollywood the infestation was so heavy that 86 per cent of the 1946 growth and 97 per cent of the buds were destroyed, and yet the aggregate parasitization was within 9 per cent of that at Fish Creek Pond, where the infestation was comparatively light and where only 32 per cent of the 1946 growth

and 5 per cent of the buds were destroyed.

In addition to the detailed observations made at the study plots, small collections of hibernating larvae were made in five areas on the periphery of the heavily infested area. In each area there was evidence of considerable budworm feeding in 1945. Nevertheless only small numbers of hibernating larvae were obtained, and practically no full-grown larvae or pupae could be found. Although parasitization of hibernating larvae by *Apanteles* and *Glypta* was high (40 to 60 per cent), the mortality in that stage fails to account for the great reduction in host population that must have occurred. Such a marked reduction in five widely separated areas on the edges of an epidemic infestation covering 3000 square miles seems noteworthy.

Table 5.—Parasitization of the spruce budworm at seven collection points[1] in Colorado in 1945.

Collection Point	Per Cent Parasitization by—			
	Apanteles and *Glypta* (hibernating larva)	*Madremyia*, *Ceromasia*, and *Omotoma*	*Phaeogenes*, *Ephialtes*, and *Itoplectis* (pupae)	Aggregate[2] Per Cent Parasitization
Endo Valley	52	24	12	68
Crocker Ranch	28	17	7	44
Glen Haven	32	23	10	53
Peaceful Valley	24	12	2	34
La Veta	63	15	11	72
San Isabel	43	15	22	62
Clinetop	12	34	8	47

[1] The first four collection points are in the vicinity of Estes Park. Two points, Buffalo Creek and Indian Creek, are omitted, because no pupal collections were made.
[2] See formula given in table 4, footnote 1.

In Colorado.—Studies regarding the natural-control factors affecting the spruce budworm in Colorado have been limited mostly to determining the species and the relative importance of the parasites present, and to the recovery of desirable parasites for shipment to the East. In 1945 a general idea regarding parasitization was obtained by dissecting and rearing host material from several points. The principal point of collection was Estes Park, where a heavy infestation had been under way for several years and where there was considerable mortality of Douglas fir. This infestation practically disappeared at the end of the season. A killing frost on June 16 destroyed a considerable proportion of the new buds, and undoubtedly the budworm population was greatly reduced. Parasitization was high. Budworm moths were fairly common at the end of the season, however, and at least a light infestation in 1946 was anticipated. Actually no new egg clusters were found in the fall of 1945, although considerable time was spent searching for them, and practically no larvae could be collected in 1946. In fact it was impossible to collect large numbers of larvae at any of the 1945 points from which collections were made in 1946.

Apanteles fumiferanae and *Glypta fumiferanae* were abundant at all collection points, and *Glypta* was probably the most important parasite in the Colorado infestations in 1945. Combined parasitization by these species ranged from 19 to 63 per cent. Aside from these two species very few parasites were recovered from the larvae. A few *Phytodietus fumiferanae* cocoons were obtained, and the larvaevorid fly *Madremyia saundersii* (Will.) emerged from 2 to 6 per cent of the larvae. This species also emerged from budworm pupae, usually in small numbers, but at one point near Estes Park 12 per cent and at Clinetop 14 per cent of the pupae produced *Madremyia*. Two larvaevorids common in Colorado, *Ceromasia auricaudata* and *Omotoma fumiferanae*, attack budworm larvae but do not emerge until the host has pupated. Combined parasitization by these species ranged from 11 to 18 per cent, with *Ceromasia* generally much more abundant than *Omotoma*. Adults of both species were conspicuous in the field. *Phaeogenes hariolus* Cress. was the outstanding pupal parasite in Colorado with from 6 to 19 per cent of the pupae parasitized. Small numbers of pupae were also parasitized by *Itoplectis conquisitor*, *Itoplectis obesus* Cush., and *Ephialtes ontario*. *Itoplectis obesus* was fairly important at Clinetop, where it parasitized about 7 per cent of the pupae.

The work in Colorado in 1945 was conducted primarily as a survey; however, in several respects it fails to give a very accurate picture of budworm parasitization. No egg collections were made. Practically all larval collections were made by beating the low branches of infested trees over cloth mats and picking up the larvae that fell. Probably some external-feeding parasites, such as *Phytodietus fumiferanae* and *Microbracon politiventris* (Cush.), were dislodged and lost, and a good many

larvae parasitized by *Apanteles* were overlooked because they were stunted in size. Nevertheless, it seems worthwhile to present the data in table 5, showing percentage parasitization by the most common parasites and aggregate per cent parasitization at several collection points. Per cent parasitization of small larvae was obtained by dissecting host material. Similar data for large larvae and pupae were obtained by rearing parasites and moths from pupae collected in the field.

In 1946 about 62,000 budworm larvae were collected in three small infested areas about 12 miles south of La Veta, Colo. This material was reared in order to obtain parasites for shipment east, and a total of 13,312 parasites, including 11,150 *Ceromasia*, 1150 *Madremyia*, 809 *Omotoma*, and 203 *Phytodietus*, were sent to the Adirondacks. An actual record of parasitization could not be made, because species such as *Apanteles* and *Glypta*, which were not desired, were discarded. It was estimated that at least 50 per cent of the collected material was parasitized.

Surprisingly enough, no new egg clusters could be found in the area at the end of the season. It is possible that eggs were laid high in the trees, where they could not be observed, so a final appraisal can not be made until 1947. There was, however, a tremendous reduction in the budworm populations at all 1945 collection points, and it is possible that the pest has also practically disappeared from the 1946 collection areas. There appear to be no heavy infestations on the eastern slopes of the Rocky Mountains in Colorado at the present time. This fact seems particularly noteworthy, because heavy outbreaks have existed there during at least the last 7 or 8 years. There is still a heavy infestation on the Uncomphagre National Forest in southwestern Colorado and also on the Carson National Forest in northern New Mexico. Plans have been laid to conduct rearing work in the Uncomphagre National Forest in 1947.

SUMMARY.—In 1945 the Bureau of Entomology and Plant Quarantine initiated an intensive program of study on the spruce budworm, *Archips fumiferana* (Clem.), including the natural-control factors affecting the pest. A number of study plots have been established in the Adirondacks, in New York, where a heavy infestation broke out in 1945. Two species of parasites not present in the East, have been obtained in Colorado, and Canadian entomologists have supplied several colonies of parasites obtained in British Columbia for release in the Adirondacks. Plans have been laid to collect *Compsilura concinnata* Meig. in the East in 1947 for liberation in Colorado infestations.

A list of 45 primary and 7 secondary parasites of the budworm has been compiled from records made during this study and from the literature. Birds are important predators on the budworm, but apparently they are more effective in light infestations. Very few diseased larvae or pupae have been observed. In some years late spring frosts kill large numbers of larvae.

Parasitization has been generally high in both heavy and medium infestations in the Adirondacks and also in Colorado. Aggregate parasitization in the Adirondacks ranged from 49 to 81 per cent at 11 study plots in 1946. In Colorado aggregate parasitization ranged from 34 to 72 per cent at 7 collection points in 1945, but two factors recorded in the Adirondacks, egg parasitization and mortality of fourth-instar larvae, were not measured. Heavy infestations which have been under way for at least 7 or 8 years on the eastern slopes of the Rocky Mountains in Colorado have now practically disappeared.—10-14-47.

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Fluctuations in Insect Populations Associated with Aerial Applications of DDT to Forests

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The advent of DDT and its dispersal by airplanes ushered in a new era in the control of insects that devastate large forest areas. Since early in 1945 a number of large operations conducted for the control of defoliating insects have proved eminently successful. The marked control obtained with low dosages of DDT gives encouragement for its use against epidemic forest pests. Heretofore the spraying of forests has not been considered economically feasible. The potency of this new insecticide has been stressed by many scientists and writers. Even before large-scale tests could be conducted and evaluated carefully, certain entomologists and others condemned its use because they feared disruption of the so-called balance of nature and painted vivid pictures of catastrophic losses. These reports involved little experimentation and were based largely on theoretical considerations.

Most biological scientists appreciate the diversity and abundance of insects in a forest and have some idea of the importance of insects as food for mammals, birds, fishes, amphibians, and other animals. They also recognize the important role of predators and parasites in controlling animal populations. In turn, they know of instances where these regulators of populations have been overwhelmed by the effects of extreme meteorological conditions. The interrelationships between animal communities in the forest are complex, and when another factor is added, such as widespread spraying with an insecticide, the problem is not simplified. Recognizing these difficulties and realizing the need for definite information on the effects of DDT on both terrestrial[1] and aquatic animals, early in 1945 the Federal Bureau of Entomology and Plant Quarantine and the Fish and Wildlife Service initiated cooperative studies to obtain this information. Several state and private agencies assisted in carrying out some of these studies.

Several study areas were established for the express purpose of treating them with DDT by airplane for studying the effects of a given dosage on the entire fauna. Other studies were made of populations in plots within larger acreages that were being sprayed for the control of forest pests. Some of these areas were studied again one year later. The spraying of additional forest areas in several states during 1946 and 1947 offered an opportunity for other biologists representing several institutions to make independent investigations of the over-all effects of different dosages of DDT on plant and animal communities. A general summary of the effects of DDT on fish and wildlife has been given by Cottam & Higgins (1946), and more detailed information regarding some of these studies has been published separately by others in the Fish

[1] Special acknowledgment is made to H. K. Townes, R. I. Sailer, and H. H. Swift of this Bureau for collaborating in the 1945 terrestrial studies, a detailed account of which will be published elsewhere.

and Wildlife Service. The results of the 1945 studies on aquatic insects are also available (Hoffmann *et al.* 1946), and it is planned to present a detailed report of the investigations on terrestrial insects at an early date elsewhere.

From the 1945 studies it appeared that the relatively stable aquatic environments were more likely to suffer from DDT applications than were other habitats in the forest. Therefore, most of our entomological studies for the last two seasons have been directed toward an evaluation of the effects of DDT contaminating fresh-water streams, such as would occur during a regular spraying program for control of forest insects. The purpose of this paper is twofold—to present the more general conclusions reached to date regarding fluctuations in terrestrial insect populations attributable to different dosages of DDT under variable conditions, and to give specific information on the results of airplane applications of DDT to streams, including data on the recovery of fish-food organisms one year later. All per cent reduction figures were computed by using the formula $(X-Y)$ $100/X$, where X is the per cent survival in the control area and Y is the per cent survival in the sprayed area.

EFFECTS ON TERRESTRIAL INSECTS.—Since most of the areas studied were relatively small, consisting of from 100 to 600 acres, sampling was stressed in the central part of each area in order to minimize the effects of immigration of insects from adjacent untreated forest. Great care was used to select check plots which were at least one air mile from the sprayed plots. Even where the general forest type and understory appeared to be similar, the pre-treatment numbers of certain insect species differed widely in the plots. In each plot population levels were ascertained before the spray was applied, so that comparisons could be made with measurements taken at intervals after the spraying. The over-all objectives were to determine the effects of DDT on different species and groups of insects under field conditions, with special attention to biological control agents and their hosts, the increase of species resistant to the poison due partly to the reduction of their natural enemies, and the duration of the residual effect of the poison.

In an effort to obtain a reliable index of insect populations in the forest, many collecting and trapping methods were utilized to sample different ecological habitats. Arboreal species were captured on sheets under the trees by tree jarring, and also in cloth-bottom trays placed on the ground to catch the insects as the fell after being affected by the spray. Flying insects were captured in light traps, fly traps, and box area traps, and on sticky trap boards. The ground species were taken in traps baited with fish or molasses, and in modified Berlese funnels. Other data were obtained by sweep-net collections and by general observations. Thousands of specimens were collected, identified, and tabulated during the course of these studies, and data on approximately 600 species or groups have furnished information on the over-all effects of DDT on forest insects other than those toward which the control effort was directed.

One woodland area studied was near Scranton, Pa. It was composed of open beech and maple stands and considerable overgrown swampy pasture land. On June 9, 1945, it was sprayed with a DDT-oil solution from a biplane at the rate of 1 pound of DDT per acre. The spray caused an almost immediate and pronounced effect on many species of insects. Of 1186 specimens collected from trays placed beneath trees, 52 per cent dropped within two days and 85 per cent within a week after the spraying. The spray was particularly effective against small caterpillars, including two species of cankerworms. Psyllids, small moths, and many kinds of small flies were killed in numbers. A sweep collection made three weeks after the spray was applied yielded many more specimens than did a similar sweep taken a day before the spraying, probably because the pre-treatment collection was made early in the year. A number of species were taken for the first time in the later collection.

Another experimental area included 117 acres of mature deciduous bottomland forest located near Bowie, Md. On the evening of June 5, 1945, it was sprayed with a DDT-oil solution at the rate of 2 pounds of DDT per acre. A slight breeze drifted some of the spray for more than one-fourth mile from the point of application. This forest has a closed canopy, which screened out much of the spray as

it fell toward the ground. The chemical analysis of spray deposit in petri plates exposed in open sites indicated an average deposition of 0.6 pound of DDT per acre, whereas the deposit beneath the tree canopy averaged only 0.05 pound.

At the dosage of 2 pounds of DDT per acre many insects were killed within a few hours after the spray application. However, the effect was not prolonged, and most of the species studied were alive in considerable numbers 2 or 3 weeks later. Tree-inhabiting caterpillars appeared to be eliminated by the spray. Moths as a group were reduced by about 70 per cent, but by the end of 3 weeks the populations in the sprayed and unsprayed areas were similar. The Hymenoptera as a whole were profoundly affected shortly after the spraying, but about a month later were present in normal numbers. Of the Diptera, only the calypterate flies were seriously affected; they sustained a loss of about 85 per cent in numbers, and there was little indication of recovery for 2 months. Several leaf-feeding beetles were also greatly reduced in numbers. Aphids sheltered on the undersides of leaves were mostly not affected and probably increased in numbers later. Many of their parasites and predators appeared to be unaffected. Most of the beetles frequenting the ground, such as carabids, silphids, and staphylinids, were not adversely affected. All the arachnids fared well, with the exception of phalangiids, which were almost eliminated.

Early in 1945 a square-mile study plot was established within a 1200-acre tract of second-growth deciduous forest in a mountainous section near Moosic, Pennsylvania. Because of inclement weather, spraying of the study area extended from May 20 to June 1, and the periphery was not completed until June 9. The DDT-oil solution was dispersed by biplanes at between 4 and 5 pounds of DDT per acre over the central plot. Intensive studies were made here for 3 months after the spraying and incidental observations were made the following year. Observations made within 3 days after the spraying showed only about 10 per cent of the conspicuous part of the arthropod fauna to be left. Most of the flying insects were killed by the spray as it settled earthward and there was no apparent recovery for at least 2 weeks (including considerable rainy weather), after which they began to increase gradually. Six weeks after the spraying, many species had attained one-third of their pre-treatment abundance. By this time the residual effect of the spray was wearing off, and immigrants and many insects emerging within the area were able to survive. Moreover, some of the parasitic and predaceous forms were taken in increasing numbers, their abundance in many cases following closely that of their hosts. Many species did not attain pre-treatment numbers until 3 months after spraying.

Many species of tree-inhabiting caterpillars were eliminated by the spray. The caterpillars infesting low vegetation were initially reduced, but gradually became as abundant as before. The majority of the hymenopterous parasites of caterpillars, particularly Braconidae and Ichneumonidae, were almost annihilated by the spray, but recovery followed so that their numbers were perhaps one-fourth of normal at the end of 3 months. The larger moths were apparently unaffected, whereas the smaller ones appeared to be moderately reduced. Flies, particularly the calypterates, were almost eliminated shortly after the spraying and showed little reestablishment that year. Some of the tree-inhabiting chrysomelids, cicadellids, and membracids were greatly reduced by the spray. Insects feeding or resting in places where they were protected from direct exposure to the spray were unaffected. This was true for psyllids feeding on the undersides of leaves, scale insects under their protective coverings and Collembola dwelling beneath bark scales. Many of the ground-inhabiting insects, including beneficial scavengers and predators, were not seriously affected. Several families of flies and their various hymenopterous parasites were able to continue successful breeding in the humus. A few of the ground beetles and carrion-feeding beetles were probably eliminated, but the majority survived the spray. Though ants were affected by the spray, their numbers were diminished only the first week after the application. In general the soil fauna was not reduced by the single heavy spray application. Spiders were variously affected, species living in exposed webs being killed in larger numbers than those in more protected situations.

Two noticeable disruptions in arthro-

pod populations occurred as a result of this heavy DDT application. Pre-treatment measurements indicated a normal aphid population and a sufficient number of parasites and predators to maintain a balance in numbers. Although many aphids in exposed positions were killed by the spray, others flourished on the undersides of leaves and later on uncontaminated new growth, probably because their enemies were more drastically affected by the spray. By July 8 a widespread outbreak involving at least 14 species of aphids on the principal forest trees of the area. The understory plants were glazed with copious quantities of honeydew, which later became unsightly because of the sooty fungus growing on it. Aphid predators (adult cantharids, mirids, lygaeids, nabids, and anthocorids; also syrphid, coccinellid, and chrysopid larvae) gradually responded to the abundance of their hosts and became more numerous. The numbers of predators, however, were not sufficient to cope with the ever-increasing aphid population. The ultimate check on the aphids resulted from an exceedingly heavy rain of 2.3 inches that fell in the area during the night of July 14, continuing into the morning of July 15. It is estimated that about two-thirds of the aphids were beaten off the leaves and destroyed. The remaining aphid population did not appear to cause important damage, and observations a year later indicated a population similar to that observed before the spray was applied.

The other outbreak involved a mite, *Paratetranychus ununguis* (Jac.). It seemed likely that the destruction of *Coniopteryx vicina* Hagen, an important mite predator, by the spray was in part responsible for the outbreak. The mite was common on oak leaves in August 1945, but no damage was evident. On May 29, 1946, damage to red maple was particularly noticeable. The mites feeding on the leaves caused a fine stippling, and when these etiolated areas coalesced the leaves became conspicuously blotched. By the following August the mite population had disappeared.

On July 1 and 3, 1947, approximately 90 acres of a 5-year-old burn in forest land on the grounds of the Agricultural Research Center at Beltsville, Md., was sprayed at the rate of 5 pounds of DDT per acre. The application was made with a plane under fair weather conditions. Chemical analyses of spray-deposit samples taken in the center of the plot showed a range of 1.75 to 7.0 pounds of DDT per acre. As with other sprayings at this dosage, the effect upon insects shortly after the application was very great. A careful examination of trails and small water holes revealed vast numbers and many kinds of affected insects. Two of the most abundant insects decimated by the spray were *Philaenus leucophthalmus* (L.) and *Popillia japonica* Newm. The most common insects seen 2 days after the spraying were aphids, flies, butterflies, ants, and wasps.

Late in July, 1947, an experimental plot of 194 acres of lodgepole pine forest in the Teton National Forest near Wilson, Wyoming, was sprayed at the rate of 7.5 pounds of DDT per acre in an attempt to control the mountain pine beetle, *Dendroctonus monticolae* Hopk. The DDT-oil solution was dispersed in two equal dosages 1 week apart, by an airplane. The first application was made on July 23 under ideal weather conditions. Tray catches after the first application showed that large numbers of Diptera, mirids, psyllids, springtails, Hymenoptera, Ephemeroptera, caterpillars, and small lepidopterous adults (mostly a leaf miner, *Bucculatrix* sp., emerging from aspen leaves) were killed by the spray. Only about one-tenth as many insects were found on the same trays after the second application. A half-hour sweep-net collection was made in the sprayed area and in a comparable check area, both before the spraying and a week after the second application. Altogether about 7000 specimens were collected, and the reduction in the insect population of the sprayed area amounted to 90 per cent.

EFFECT ON AQUATIC FAUNA.—Sections of several streams have been sprayed experimentally with DDT by airplane to determine the effects, especially on invertebrates and fish. These studies have been made on both cold-water and warm-water streams, and in each instance the U. S. Fish and Wildlife Service has carefully followed the effects on fish. All the treatments have been made at the rate of 1 pound of DDT per acre and applied in one swath by a small biplane flying directly over and parallel with the stream. This procedure insured that a maximum

amount of spray was deposited on the stream and afforded a severe test, for a much greater deposit was obtained than would have resulted from an ordinary forest spraying. The variation in amounts of spray reaching the water has been recognized, so that the practice was made of placing filter papers or glass plates on small platforms in the stream at about 500-foot intervals to catch the deposit. Later these spray deposits were analyzed chemically and the amounts determined in pounds of DDT per acre. Information on the effects of DDT on fish-food organisms was gained largely from samples of the bottom fauna taken with a stream square-foot sampler in the sprayed section and in the untreated section, both before and at intervals after the spraying. Whenever possible, an upstream portion of the stream to be sprayed was used for a check, in order to avoid the difficulty of trying to match streams. Our experience indicates considerable normal variation in species and numbers of bottom organisms in the same stream, even though sampling was confined to riffles. A minimum of three sampling stations were established on each stream—at the beginning, middle, and end of the sprayed section. In each of two streams a check station was established upstream from the head of the spray run. A station a mile or more below these sprayed areas was used to measure the effects of the poison carried downstream.

Ash Creek is a cold-water trout stream that empties into the Lehigh River near Clifton, Pa. It arises in a rhododendron swamp and for about the first mile flows beneath overhanging trees, and becomes increasingly more open in the next 2 miles. This rapidly flowing stream averages 10 feet in width and 10 inches in depth. The water is clear, and the abundance of aquatic vegetation contributes to a very rich insect fauna. A 3-mile section was sprayed with a DDT-oil solution on August 9, 1945. Chemical analyses of the spray deposits collected on filter papers indicated that on an average 0.23 pound of DDT per acre reached the stream.

Two square-foot samples of bottom fauna taken 3 weeks before and 2 weeks after the spray application showed a 90-per cent reduction in fish-food organisms at the two lowest stations (Hoffmann *et al.* 1946). The mayflies as a group were almost eliminated. One species, *Ephemerella rotunda* Morg., was present in large numbers in the post-treatment collection at the lowest station. The specimens were all small, and probably many of them did not hatch until after the spray was applied. Square-foot stream samples collected a year later showed a 39-per cent reduction at the middle station compared with the pre-treatment population, whereas at the lower station there was a 60-per cent increase. This favorable recovery was due to an increase in numbers of the following forms: *Baetis* spp., *Ephemerella rotunda*, *Simsonia* spp., and tendipedid larvae. Many species of *Baetis* have one, and a partial second, generation per year. They probably survived in the egg stage when this stream was sprayed, or became established later. The increase in tendipedid larvae was phenomenal. Probably they were able to complete their short life cycles and increase in numbers after the initial effects of the poison had worn off. The invertebrate groups that showed little or no effect from the DDT spray were the Annelida, Mollusca, Odonata, Coleoptera, Hydracarina, and Megaloptera. The Plecoptera and most Diptera showed a considerable reduction in numbers 2 weeks after the spraying, and only the dipterous larvae were present in large numbers a year later. Some species of Trichoptera were exterminated, a few were unaffected and several were taken for the first time in 1946. The Ephemeroptera, which consisted mostly of the free-ranging, stream-lined forms, were affected most severely by the treatment; however, they showed considerable recovery one year after the spraying.

DDT in an oil spray was applied at the rate of 1 pound per acre to a 0.9-mile section of St. Mary's River near Vesuvius, Virginia, on July 10, 1947. This section of the river is largely sheltered by the canopy of an almost mature mixed-hardwood forest. The width of the sprayed portion varies from 7 to 15 feet and the depth from a few inches to several feet in pools; the bottom consists mostly of large rubble. The estimated flow of the stream at the time of spraying was 2500 gallons per minute.

Three days before and 3 days after the spraying, three quantitative samples of bottom insects were taken with a square-foot stream sampler at each of five stations designated as follows: 1, 1.7 miles

Table 1.—Average numbers of invertebrates per square foot in St. Mary's River, based on three samples taken three days before and three days after the stream was sprayed by airplane with DDT-oil solution in 1947.

Invertebrates	Unsprayed Station 1		Sprayed Stations								Population at Stations 2, 3, and 4[1]
			2		3		4		5		
	Pre-spray	Post-spray	Pre-spray	Post-spray	Pre-spray	Post-spray	Pre-spray	Post-spray	Pre-spray	Post-spray	
CRUSTACEA											
Crayfish	1.7	0.3	1.0	0.3	1.7	4.3	1.0	1.0	4.7	5.3	A
EPHEMEROPTERA											
Baetis cingulatus McD.	0.7	1.7	1.7	0.0	1.3	0.0	1.3	0.0	10.0	1.0	D
Baetis sp.	0.3	3.7	1 0	0.0	1.7	0.0	2.3	0.0	1.3	4.0	D
Iron sp.	3.7	0.7	1.7	0.0	3.7	0.0	3.7	0.0	0.0	0.0	B?
Paraleptophlebia guttata McD.	2.0	6.3	3.0	0.7	2.7	1.0	1.3	2.7	95.7	29.7	B
Paraleptophlebia mollis Eat.	5.0	3.3	1.3	0.3	1.3	0.0	1.0	0.0	0.7	2.7	C
Pseudocloeon carolina Bks.	1.0	0.0	0.7	0.0	1.3	0.0	1.7	0.0	7.3	0.0	—
Stenonema spp.	2.3	1.6	2.3	0.0	1.3	0.0	0.0	0.0	1.4	2.7	D
PLECOPTERA											
Acroneuria abnormis Newm.	2.3	1.3	1.0	0.7	2.3	0.3	1.0	0.3	0.0	0.0	B
Acroneuria lycorias Newm.	1.0	0.0	9.7	0.3	6.0	0.7	2.0	0.7	0.0	0.3	B?
Leuctra sp.	9.0	24.7	111.3	8.0	44.7	9.0	54.3	14.0	137.7	66.3	C
Peltoperla arcuata Ndm.	1.7	0.0	1.0	0.3	5.0	1.3	1.0	2.7	0.0	0.0	B?
Pteronarcys proteus Newm.	0.0	0.0	0.7	1.7	2.0	0.3	1.3	1.3	0.0	0.0	A
MEGALOPTERA											
Nigronia serricornis (Say	6.7	11.0	9.0	1.3	7.0	4.0	1.0	2.7	0.0	0.0	C
COLEOPTERA	0.3	1.3	1.7	0.0	0.3	0.3	1.0	0.7	6.0	15.0	C
TRICHOPTERA											
Cheumatopsyche spp.	48.3	32.0	147.7	1.3	135.0	2.3	23.3	1.7	15.7	8.7	C
Hydropsyche near *slossonae* Bks.	4.7	0.3	3.3	0.0	5.3	0.0	3.0	0.0	1.3	0.3	B?
Hydropsyche spp.	4.4	0.7	2.7	0.0	1.7	0.0	7.3	0.0	5.4	2.3	B?
Trentonius distinctus (Wlk.)	3.3	3.7	5.0	0.0	14.7	0.0	18.0	0.7	39.3	0.0	C
Trentonius distinctus, pupae	1.3	0.3	0.7	0.3	1.3	0.3	1.0	0.7	2.3	0.7	A
Psychomyiidae	2.0	1.0	5.3	0.0	2.7	0.3	2.0	0.3	0.3	0.0	C
DIPTERA											
Hexatoma spinosa (O.S.)	2.7	4.3	1.3	1.3	1.3	2.0	3.0	0.3	1.3	1.0	B
Tendipedidae	1.6	5.0	10.4	1.7	9.3	2.3	11.1	2.0	23.0	1.4	C
Simuliidae	0.3	0.0	0.7	0.0	1.3	0.0	0.0	0.0	5.3	0.0	—
OTHER AQUATIC INSECTS	2.6	2.0	2.9	1.0	4.0	0.0	4.0	0.3	14.7	0.6	—
Totals	108.9	105.2	327.1	19.2	258.9	28.4	146.6	32.1	373.4	142.0	
Per cent reduction		3		94		89		77		61	

[1] A, not affected; B, reduced; C, greatly reduced; D, exterminated.

above sprayed section on the same stream, check; 2, 0.2 mile below head of spray run; 3, 0.4 mile below; 4, 0.9 mile below; and 5, 4.8 miles below the head of spray run. Analyses of the spray deposits obtained on glass plates distributed 100 feet apart in the treated section averaged 0.17 pound of DDT per acre, range 0.0 to 1.38 pounds. Because of the forest canopy covering the stream, large numbers of terrestrial insects of diverse orders were affected within a few minutes after the application and fell into the stream. The greatest numbers of affected aquatic forms were collected in drift samples 2 to 3 hours later.

The effect of the spray on fish-food organisms in this stream (Table 1) was probably more severe than for Ash Creek, in spite of a heavier canopy. Possibly the steep gradient and the large rocks in St. Mary's River caused the spray to be churned into the water and enhanced its effect. Table 1 shows also that some species were more resistant to the poison than others. Mayflies and caddis flies showed the greatest losses, but all orders had survivors 3 days after the spraying. The apparent reduction of 61 per cent in the total number of bottom organisms taken 4.8 miles below the head of the spray run suggests that lethal amounts of DDT in an oil solution are carried for a considerable distance down stream. However, the river was broad and meandered through an open pasture at station 5; hence this station differed ecologically from the other stations.

On July 24, 1946, a 0.9-mile section of Back Creek, a warm-water bass stream, located near Glengary, W. Va., was sprayed with a DDT suspension at the rate of 1 pound of DDT per acre. The average width of this section of the stream is 72 feet, the average depth is 21 inches, and the rate of flow is about 21

Table 2.—Average numbers of invertebrates per square foot in Back Creek based by airplane with DDT-water suspension in

INVERTEBRATE[1]	1946—DDT-WATER SUSPENSION						
	Unsprayed Section		Sprayed Section				Population at Stations 3 and 4[2]
			Station 3		Station 4		
	Pre-spray	Post-spray	Pre-spray	Post-spray	Pre-spray	Post-spray	
MOLLUSCA							
Nitocris carinatus (Brug.)	13.2	11.8	5.0	12.0	21.6	37.4	A
Sphaerium stamineum Lmk.	1.8	1.6	0.0	0.0	0.0	0.0	—
EPHEMEROPTERA							
Baetis spp.	3.6	3.4	2.0	0.0	2.2	0.0	D
Heptagenia maculipennis Walsh	2.8	1.8	5.8	0.0	7.6	0.0	D
Iron rubidus Trav.	1.2	0.0	1.0	0.0	0.2	0.0	D
Isonychia albomanicata (Ndm.)	7.2	17.2	5.2	0.0	2.8	0.0	D
Pseudocloeon carolina Bks.	0.8	1.0	1.4	0.0	1.8	0.0	D
Stenonema near *fuscum* (Clem.)	6.0	1.8	14.2	0.0	3.6	0.0	D?
Stenonema rubrum (McD.)	5.8	9.2	4.8	0.0	5.2	0.0	D
Stenonema spp.	0.4	4.4	0.0	0.0	4.0	0.0	D
PLECOPTERA							
Acroneuria internata (Wlk.)	5.6	4.0	4.8	1.4	2.6	0.6	C
Neoperla clymene (Newm.)	2.6	0.4	1.2	5.2	4.2	2.6	A
Neophasganophora capitata (Pict.)	1.4	1.6	2.2	1.2	1.2	0.4	B
MEGALOPTERA							
Corydalis cornutus (L.)	2.2	4.0	1.0	1.4	0.8	1.4	A
Nigronia serricornis (Say)	1.2	3.2	0.6	0.2	0.8	0.4	C
COLEOPTERA							
Heterlimnius trivittatus (Brn.)	2.8	6.4	5.2	0.2	2.6	0.0	C
Microcylloepus pusillus (Lec.)	1.8	10.2	3.0	0.0	4.0	0.0	D
Psephenus herricki (Dek.), larvae	0.4	0.4	0.8	0.8	1.4	0.2	A
Simsonia sp., larvae	3.6	2.8	5.2	2.8	3.4	1.8	B
Stenelmis near *mera* (Sand.)	4.4	10.8	10.8	3.6	6.8	1.4	C
Stenelmis spp., larvae	6.6	9.6	15.2	17.8	16.4	11.8	A
TRICHOPTERA							
Chimarra obscura (Walk.)	14.0	21.2	28.0	0.8	17.6	1.0	C
Chimarra obscura, pupae	2.2	0.4	3.4	3.0	1.8	0.6	A
Chimarra socia Hag.	9.0	10.8	9.2	0.0	13.2	0.0	D
Cheumatopsyche spp.	10.4	8.4	18.6	0.0	10.2	0.2	C
Hydropsyche spp.	9.4	3.6	5.8	0.4	4.6	0.0	C
Macronemum zebratum (Hag.)	0.6	0.8	4.2	0.0	4.0	0.2	C
DIPTERA							
Tendipedidae	2.0	0.4	0.4	0.0	2.2	0.6	B?
Hemerodromia sp.	1.4	0.4	1.6	0.4	1.0	0.2	B?
OTHER AQUATIC INSECTS	2.0	6.2	2.8	2.0	5.2	1.2	—
Totals	126.4	157.8	163.4	53.2	153.0	62.0	
Per cent reduction		0		74		68	

cubic feet per second. This sluggish stream is composed of long pools separated by short gravel and rubble riffles. The banks of the stream are steep and are bordered with tall hardwood trees. The spray was applied early in the morning when there was little wind movement, and a uniform deposit was obtained. Analyses of the DDT deposits on glass plates indicated an average of 0.39 pound of DDT per acre, range 0 to 1.1 pound.

General observations the first day indicated that the suspension spray did not

on five samples taken one week before and one week after the stream was sprayed 1946, and with DDT-oil solution one year later.

	1947—DDT-Oil Solution						
	Unsprayed Section		Sprayed Section				
			Station 3		Station 4		
Invertebrate[1]	Pre-spray	Post-spray	Pre-spray	Post-spray	Pre-spray	Post-spray	Population at Stations 3 and 4[2]
MOLLUSCA							
Nitocris carinatus (Brug.)	5.4	11.2	4.8	13.4	14.4	28.6	A
Sphaerium stamineum Lmk.	1.6	1.6	0.2	0.4	0.4	0.0	A
EPHEMEROPTERA							
Baetis spp.	7.2	42.4	15.6	0.0	11.0	0.0	D
Heptagenia maculipennis Walsh	2.8	9.0	3.2	0.0	0.6	0.0	D
Iron rubidus Trav.	0.2	0.6	0.4	0.0	0.8	0.0	D
Isonychia albomanicata (Ndm.)	2.8	20.2	9.4	0.0	16.0	0.0	D
Pseudocloeon carolina Bks.	3.2	5.6	4.4	0.6	5.0	0.0	C
Stenonema near *fuscum* (Clem.)	3.6	2.6	2.6	0.0	1.2	0.0	D?
Stenonema rubrum (McD.)	12.2	21.6	10.8	0.0	9.6	0.0	D
Stenonema spp.	0.6	3.6	5.6	0.0	5.4	0.0	D
PLECOPTERA							
Acroneuria internata (Wlk.)	7.8	13.8	17.2	9.4	18.4	1.6	C
Neoperla clymene (Newm.)	1.0	1.0	0.0	0.4	0.0	0.0	—
Neophasganophora capitata (Pict.)	4.0	1.8	2.0	0.2	1.4	0.0	B?
MEGALOPTERA							
Corydalis cornutus (L.)	2.4	8.8	2.6	3.8	2.4	2.4	A
Nigronia serricornis (Say)	18.6	20.0	3.8	5.2	3.6	1.8	A
COLEOPTERA							
Heterliminius trivittatus (Brn.)	10.2	6.8	14.0	0.6	3.2	0.0	C
Microcylloepus pusillus (Lec.)	0.0	5.8	0.4	0.2	1.0	0.0	—
Psephenus herricki (Dek.), larvae	0.8	1.0	1.0	3.0	1.2	2.0	A
Simsonia sp., larvae	7.0	8.2	0.2	1.0	1.6	0.8	A
Stenelmis near *mera* (Sand.)	14.6	26.8	13.2	1.4	6.0	0.2	C
Stenelmis spp., larvae	12.4	16.0	4.4	3.0	1.2	2.0	A
TRICHOPTERA							
Chimara obscura (Walk.)	55.6	81.4	43.8	0.0	74.6	0.2	C
Chimarra obscura, pupae	1.0	2.0	2.2	1.6	3.6	1.8	B
Chimarra socia Hag.	24.2	25.6	28.0	0.0	39.8	0.2	C
Cheumatopsyche spp.	7.2	18.0	3.8	0.0	1.8	0.0	D
Hydropsyche spp.	4.2	21.2	8.2	0.2	12.6	0.6	C
Macronemum zebratum (Hag.)	2.2	4.6	0.0	0.0	0.0	0.0	—
DIPTERA							
Tendipedidae	1.2	1.0	0.8	0.4	0.4	0.4	—
Hemerodromia sp.	1.4	0.0	0.2	0.0	0.0	0.0	—
OTHER AQUATIC INSECTS	9.0	8.4	3.8	2.0	6.4	2.0	—
Totals	224.4	390.6	206.6	46.8	243.6	44.6	
Per cent reduction		0		87		90	

[1] Coleopterous forms are adults unless otherwise designated; other insects are immature.
[2] A, Unaffected; B, reduced; C, greatly reduced; D, exterminated.

materially reduce the numbers of surface and free-swimming Coleoptera and Hemiptera, probably because the DDT suspension did not remain widely dispersed on the surface film. Collections of drifting insects showed the rapid paralyzing effect of the poison. Of 5553 specimens taken in drift samples at intervals throughout the first day at the middle station, 90 per cent were captured within the first three hours after the spray was applied. Caddis fly larvae, chiefly *Chimarra obscura* (Walk.) and *C. socia* Hag., were greatly affected during the first

half-hour after the spraying, whereas mayflies and certain beetles did not show the effects until after 1 to 3 hours.

A week before and a week after the spraying, five quantitative samples of bottom insects were taken with a square-foot stream sampler at each of the following stations: 1, 0.5 mile above sprayed section on the same stream, check; 2, at head of spray run; 3, 0.5 mile below; 4, 0.8 mile below; and 5, 2.0 miles below the head of spray run. An estimate of the effects of the spray on the important bottom invertebrates of this stream is given in table 2. Over-all losses at station 2 amounted to 33 per cent compared with 74 and 68 per cent at stations 3 and 4, the latter losses being higher, undoubtedly because of greater dosage through accumulative effects downstream. The vegetarian mayflies were almost eliminated from the lower part of the sprayed section, while the majority of the carnivorous stoneflies were not seriously affected. Elmid beetles were reduced in numbers, but their larvae survived well. Snails did not appear to be affected by the spray.

Approximately one year later bottom samples were taken again at the same stations. Stream conditions must have improved considerably, for there was a decided increase in the average number of invertebrates per square foot taken at the check station. A great increase occurred also in all the sprayed stations, in spite of the fact that about 70 per cent of the invertebrate population had been destroyed by the DDT suspension spray the year before. The pre-spray data for 1947 in table 2 show not only that this recovery in numbers of fish-food organisms was general, but that those species most abundantly represented were those that were severely reduced in 1946.

The second spraying of the same section of Back Creek was made under ideal weather conditions on July 23, 1947. The same pilot flew the same airplane and the rate of application was also kept constant; so the only difference in the treatment was that an oil solution of DDT was used instead of a suspension. Analyses of the spray deposits obtained on glass plates showed that on an average 0.27 pound of DDT per acre reached the water, range 0.0 to 1.86 pounds. This spray, in contrast to the suspension used in 1946, caused an almost immediate and pronounced effect upon many species of surface Hemiptera and aquatic Coleoptera. General observations also indicated that many more terrestrial insects were killed this year than last year. Surface-drift samples of aquatic insects were taken, but for some unexplainable reason considerably fewer insects were captured this year. The bottom samples, on the other hand, show about a 90-per cent reduction at stations 3 and 4, and the species most severely affected were practically the same as those adversely affected by the suspension. These data confirm earlier experimental work in showing that DDT applied as an oil solution is more toxic to aquatic life than is a wettable DDT applied as a suspension. Although unimportant losses of small fish occurred after both sprayings, the greatest loss of fish was caused by the oil spray.

SUMMARY.—Since the spring of 1945 a number of large forest areas have been sprayed with DDT either for the control of destructive pests or for experimental studies to determine the effects of such sprayings on animal communities. Study plots of 100 to 600 acres were established in some of these areas to observe effects on the more abundant insect species. In some instances it was possible to follow closely the residual effect of the poison for 1 to 3 months after the spray application. The applications have ranged from 1 to 7.5 pounds of DDT per acre. Regardless of dosage, the kill of insects shortly after the spraying was tremendous. The residual toxicity of the 1-pound dosage lasted for about a week, and of the 2-pound about 2 weeks; the 5-pound dosage was severe after 6 weeks, and there was not much recovery until after 3 months.

Arthropods showed great variation in susceptibility to DDT. This variation was due in part to the degree of the insects' contact with the poison, which is influenced by their individual ecology, habits, seasonal life history, or structure. Exposed species were affected more than those protected by foliage, bark, burrows, or by the leaf mold and soil. The timing of the spray was most important. Those species caught in a susceptible stage, such as caterpillars and flying adults of many orders, were severely reduced. Hairy species, such as butterflies, moths, and bees, seemed quite resistant. After one spraying at the rate of 5 pounds of DDT

per acre, there was a loss of natural enemies of aphids and mites, and outbreaks of both groups developed, which however were of short duration.

Studies to date indicate that a single airplane application of DDT to the forest at the rate of 1 pound of DDT per acre, which is sufficient to control many forest defoliators, does not seriously affect the terrestrial arthropod fauna, since only a few species might be eliminated. Dosages of 5 pounds or more of DDT per acre threaten extermination of many species, but do not cause catastrophic losses.

The results of 1-pound-per-acre airplane applications of DDT to fish-food organisms in both cold-water and warm-water streams are reported in this paper. In the case of DDT-in-oil sprays, about 90 per cent of the invertebrates were destroyed at the lower stations in the treated sections of three streams. Losses of invertebrates in a stream sprayed with a suspension at the same dosage amounted to only about 70 per cent at the lower stations. Field studies to date show that oil solutions of DDT are more toxic to invertebrates than are suspensions of DDT. Regardless of the treatment, all the streams studied had more invertebrates per square foot a year later than at the time of the pre-treatment sampling. In one stream the species composition had changed, and some forms with a short life cycle had replaced others with a longer life cycle which had been almost eliminated by the spray.

To summarize broadly, it appears that airplane applications of DDT at the rate of 1 pound of DDT per acre, which affords good control of many forest pests, cause no permanent damage to most forest- and stream-inhabiting animal populations.—5-1-48.

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Ecological Notes on the Deer Fly at Summer Lake, Oregon[1]

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The deer fly, *Chrysops discalis* Will. is a severe pest of man and animals in the vicinity of Summer Lake, Oregon. The population of flies is so great that ranching activities are seriously curtailed. Milk production on dairy farms bordering the lake is reputed to decline 40 to 50 per cent during the season of fly activity. These flies are also carriers of tularemia. Gjullin (1945) has reported on the abundance of this pest and presented a number of biological notes.

The following observations were made during the summers of 1946 and 1947 while the authors were conducting tests on the use of chemicals for the control of this pest.

INCIDENCE OF ADULTS.—The large breeding area produces a high population of adults and it is comparatively easy to capture them with an insect net whenever the weather is favorable. To obtain information on the daily and season al abundance of this fly, a simple method of collecting adults was initiated in 1946. A standard-size insect net was swung over the head 4 times, after which 3 forward steps were taken. This procedure was repeated for 2 minutes, during which time 32 swings of the net were made. Collections were made each day between 11 and 1 in a sagebrush and sedge area about 1000 feet from the lake shore.

The catches varied considerably from day to day probably owing to differences in wind velocity, air temperature, and fly emergence. The greatest number taken at one collection period was 133 in 1947. The collections were totaled for 5-day periods and are given in figure 1. The peak abundance for both years occurred during the latter part of July and the first part of August.

OVIPOSITION HABITS.—Gjullin (1945)

[1] Oregon State College cooperated on part of the work reported.

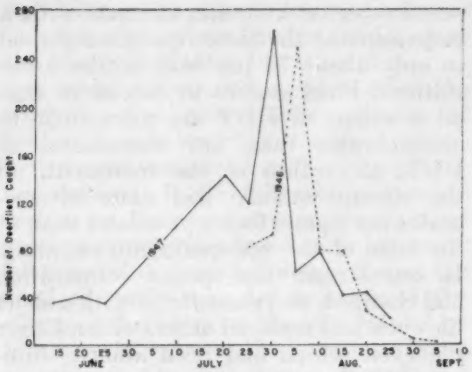

FIG. 1.—Seasonal incidence of the deer fly at Summer Lake, Oregon, as determined by daily collections with 32 swings of a net.

reported oviposition on the sedge, *Scirpus americanus* Pers., growing on the northern part of the lake. Although most of the eggs are deposited on this plant, they have also been observed on *S. paludosus* A. Nels. Since practically three-fourths of the southern part of the lake is devoid of vegetation, the oviposition is restricted almost entirely to the sedge area on the northern end. Eggs have not been found on either wet or dry soil.

An observation of interest was that the flies will also oviposit on boards, sticks, screen wire, glass, cardboard, tar paper, and other artificial objects placed in the water along the shore. When stakes were placed at some distance from the sedges, an enormous number of eggs were laid on them. As many as 30,000 egg masses were laid on a board 12 feet high and 6 inches wide in a few days' time. Eggs were deposited up to the top of this board. Approximately the same number of egg masses were laid on a piece of hardware cloth comprising 16 square feet in a 10-day period. Each egg mass contains about 450 eggs. The time required to lay an egg mass ranges from 25 to 50 minutes.

Table 1.—Average number of deer fly egg masses laid per day on wooden stakes painted different colors.

COLOR OF PAINTED STAKES	1946	1947	AVERAGE, BOTH YEARS
No paint	184	121	152
Chinese red	186	110	148
Jade green	88	54	71
Admiral green	47	87	67
Canary yellow	89	44	66
White	82	44	63
Ruby maroon	33	64	48
Pale blue	47	37	44
Brown	29	52	40
Orange	22	61	42
Emerald green	22	60	41
Black	17	62	39
Delft blue	22	41	31

To determine whether any one color was more attractive than others to ovipositing females, 13 stakes, an unpainted one and 12 painted with different colors, were exposed in the lake. Records were made of the number of eggs laid on each stake for 10 days during 1946 and 1947. Table 1 shows that the unpainted wood and chinese red were considerably more attractive than any of the other colors. Blue, brown, orange, black, and emerald green were less attractive than jade green, yellow, white, and maroon.

ADULTS TRAPPED ON ADHESIVES.—The fact that flies oviposit readily on stakes suggested that perhaps the insects could be trapped with adhesives applied to stakes or other surfaces. In preliminary tests many deer flies were caught on stakes treated with nondrying adhesives. It was believed that this method would be useful in survey and incidence studies, and that its use might also be considered for control purposes, since the prevention of oviposition and destruction of the females would be accomplished simultaneously.

Three non drying adhesives No. 1 and No. 2 being two butylene polymers[2] and No. 3 a mixture[3] containing 60 per cent of chiefly hydrogenated methyl abietate, and 40 per cent of rosin—were tested at two dosages on stakes with a surface area of 1 square foot in mid-July. The adhesives were spread on the stakes which were exposed 20 feet apart in the lake near the shoreline. The deer flies were taken off the stakes each day. The results of these tests are given in table 2. The butylene polymers were effective in trapping flies whereas the rosin mixture[2] was ineffective.

In good weather the stakes were completely covered with flies in a few hours, and it was impossible for more to adhere to the substance. A few stakes were set up in a 12-inch diameter bucket so as to catch any flies that dropped from them. About a third as many flies fell into the bucket as were stuck on the stakes. Hundreds of flies that obtained only a small amount of the adhesive on their bodies were able to fly a short distance before dropping on the water. Frequently larger stakes caught thousands of flies. For example, in a 2-day period in August, 16,872 flies were captured on a stake 6 inches wide and 12 feet high.

[2] *Tanglefoot* and *Deadline*.
[3] *Hercolyn*.

Table 2.—Average number of ovipositing deer flies trapped per square foot by adhesives applied to two smooth stakes at different dosages.

	22 GRAMS PER SQUARE FOOT			44 GRAMS PER SQUARE FOOT		
DATE	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
July 12	352	351	18	405	519	16
13	27	57	.5	128	222	0
14	58	109	0	328	518	.5
15	36	35	.5	295	408	.5
16	22	23	0	129	125	0
17	3	.5	0	19	75	0
18	2	2	0	29	71	0
19	1	1	0	5	23	0

Larval Habits.—The shallow water in Summer Lake is highly alkaline, containing 21,730 parts per million of total solids composed of sodium carbonate, sodium chloride, and sodium sulfate. The water has a pH ranging from 8.8 to 9.6 and contains a large amount of hydrogen sulfide.

The bottom of the lake is covered with flocculent ooze 1 to 5 inches deep, with an understratum of soft, sticky, blue clay. In this water and ooze there are great quantities of Crustacea, chironomid larvae, and beetle larvae, as well as deer fly larvae. The Crustacea, all typical bottom or shallow-water forms, consist chiefly of Cladocera (*Simocephalus vetulus* (O. F. Mueller), *Pleuroxus* sp., *Ostracoda* sp., *Anostraca* sp., and the copepod *Eucyclops agilis* (Koch))[4]

Population studies of deer fly larvae were made by sieving soil through 18- and 40-mesh sieves. Early in the work ooze and clay were sampled to a depth of 8 to 10 inches, but seldom were larvae found below 4 inches. Mud samples were examined over a large area, but few larvae were obtained as far as one-half mile out in the lake. The number of larvae per square foot ranged from none to 133. Mature larvae were found as early as June 12 and as late as August 26. Most of the large larvae were usually found concentrated near the water's edge.

The presence of medium and large larvae many miles from any known egg-deposition areas led to studies on how they came to these areas. In 1945 Gjullin reported that a few small larvae 6 millimeters in length were floating on the surface of the lake in the daytime. This same observation was made by the authors in 1946 and 1947.

Studies were initiated on June 12, 1947, to observe *Chrysops* larvae during the night. The moon was bright, and no larvae were seen by flashlight early in the evening. After the moon set, 30 to 40 medium and large deer fly larvae were picked from the surface of the water in 90 minutes. During this time many horse fly and beetle larvae were seen floating along with the wind and current. Subsequent night observations in June and July confirmed these first notes. In August no larvae were observed on the water surface at night. Apparently wind and currents determine the distribution throughout the lake in early spring and perhaps in the winter, and this may be the way in which larvae become concentrated in large numbers around small alkali islands or in narrow strips on the shore. Mature larvae were found on shore 500 feet from the water's edge in strips 5 to 150 feet wide and 10 to 1000 feet or more long. Some of the areas sampled showed no larvae or pupae, perhaps because wind or currents directed the floating larvae on only one side of an island or shore.

EMERGENCE.—Concentrations of pupae may be found throughout the Summer Lake area wherever there is a pond, lake, or sluggish stream. Generally they are found along the shoreline in damp but not wet, white alkali soil. In the large tule area on the northern end of the lake are numerous islands, the shores of which are good places to locate large concentrations. Here full-grown larvae and pupae are concentrated in a narrow band from 1 to 5 feet wide and up to 100 feet long. Apparently the mature larvae, which migrate from the bottom mud at night, are transported by the wind to the shoreline where they again burrow into the mud. On the southern three-fourths of the lake the pupae are found farther back from the shore and usually in a strip 1 to 200 feet wide and several thousand feet long. Pupae were abundant in this area during July in both 1946 and 1947, but during August none could be found in either year. In contrast, in the northern tule area pupae are present all summer. No adequate explanation for this difference has been given. Just prior to pupation the full-grown larvae burrow upward, opening an emergence tunnel. Pupation takes place just at the soil surface or slightly above. Early-stage pupae may be found an inch down in the tunnels.

During the period of emergence the pupal skin splits dorsally from head to thorax, and then two short splits occur over each eye. The emerging adult gradu-

[4] Crustacea identified by Mrs. Mildred S. Wilson, Corvallis, Oreg.

ally works its way upward, and the head and thorax emerge. In 1 or 2 minutes the adult falls forward, landing on its front legs, and draws its body out of the pupal skin. It then walks several inches away from the pupal case and in 10 to 15 minutes flies 50 to 150 feet toward the vegetation along the shore. Never has an adult deer fly been observed to fly toward the water.

A study of the emergence was made by placing cages over soil in areas where full-grown larvae and pupae were concentrated. The cages contained glass jars in which the adults were trapped as they emerged. The cages were sunk into the soil to a depth of 3 inches. In 1946 a cage covering 2 square feet and 1 foot high was used, and in 1947 a cage covering 25 square feet and 3 feet high was utilized. The cases were not set in the same location both years. After having been set out, they were allowed to remain undisturbed for the period of observation. It was not anticipated that single cages would give a complete picture of emergence, but the data indicate that emergence continued over a 25- to 30-day period in a single cage. Since it is not likely that larvae migrated into the cage, it is believed that the grown larvae require about 25 days to develop into pupae and emerge as adults. In 1946 the emergence per square foot ranged from 0 to 16, with an average of 3.04, as compared with an average of 0.21 and a range from 0 to 1.0 in 1947. The smaller number of flies emerging in 1947 was probably due to setting the cage over an area with a small larval population.

SUMMARY.—Preliminary studies on the ecology of deer flies *Chrysops discalis* Will. were conducted at Summer Lake, Oregon, during 1946 and 1947. Daily incidence of adults, as determined by 32 swings of an insect net, showed peak abundance in the latter part of July and the first part of August. The greatest daily catch was 133 flies.

Eggs are laid on sedges, but oviposition also occurred on boards, sticks, screen wire, glass, cardboard, tar paper, and other artificial objects placed in the water along the shore. As many as 30,000 egg masses were laid on a board 12 feet high and 6 inches wide in a few days' time. Unpainted boards and boards painted red were more attractive for oviposition than any of the other colors tested.

Enormous numbers of flies were caught on boards treated with nondrying adhesives. Under good weather conditions stakes were completely covered with flies in a few hours. As many as 16,872 flies were trapped on a board 12 feet high and 6 inches wide in 2 days.

The larvae are found in the bottom mud of the lake to a depth of about 4 inches, and are distributed fairly regularly over the lake during the spring. When full-grown they are found in large numbers along the shorelines, and probably are transported here by the wind when they come to the surface of the water during the night.

Pupation takes place in damp but not wet soil along the shorelines. Cages sunk into the soil along the shore, and allowed to remain undisturbed showed that adults emerged over a 25- to 30-day period. The average number of flies to emerge per foot ranged from 0.21 to 3.04. Under natural conditions the flies stay in the vicinity of the pupal case for 10 to 15 minutes after emergence.—3-28-48.

LITERATURE CITED

Gjullin, C. M., and Don C. Mote. 1945. Notes on the biology and control of *Chrysops discalis* Williston (Diptera, Tabanidae). Ent. Soc. Wash. Proc. 47: 236–44.

TWELFTH ANNUAL PEST CONTROL CONFERENCE AT PURDUE

The 12th Annual Pest Control Operators Conference was held at Purdue University, April 5–9, with 226 attending from 24 states and Canada, including Colorado on the West, Texas and Florida on the South, and Canada on the North. I'll send you an outline of the conference, under separate cover.

The Problem of Quarantining Plant Viruses[1]

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The passage of Public Law 290, approved July 31, 1947 amends section 1 of the Plant Quarantine Act (37 Stat. 315, 7 U.S.C. 1940 Ed. 154) by a new priviso as follows:

> "*And provided further,* That the Secretary of Agriculture is authorized to limit entry of nursery stock from foreign countries under such rules and regulations as he may deem necessary, including the requirement, if necessary, that such nursery stock be grown under postentry quarantine by or under the supervision of the United States Department of Agriculture for the purpose of determining whether imported nursery stock may be infested or infected with plant pests not discernible by port-of-entry inspection and provided that if imported nursery stock is found to be infested or infected with plant pests not discernible by port-of-entry inspection and provided that if imported nursery stock is found to be infested or infected with such plant pests, he is authorized to prescribe remedial measures as he may deem necessary to prevent the spread thereof."

The language of this new provision together with the directions issued by the Secretary of Agriculture appear to point in the direction of plant viruses at last being recognized officially as a serious menace to American agriculture. For this belated recognition we are thankful, but with it goes a responsibility upon plant pathologists, entomologists and the quarantine officials of the Nation which is not to be regarded lightly.

While the virus diseases, like fungous and bacterial diseases, of plants have been recognized for centuries their peculiar properties have been recognized only a little more than a half century. During this period, and more particularly during the last two decades, most of our detailed knowledge of plant viruses has been revealed, and yet we do not know their exact nature. We do, however, have a considerable body of information regarding the behavior of these baffling but most interesting entities which have been held almost invulnerable from the quarantine standpoint.

At your invitation I shall present some of the outstanding pertinent features of plant viruses and bring into focus some of their vulnerable points which bear on the subject of this paper.

[1] Paper presented before the American Association of Economic Entomologists, Chicago Meeting, Dec. 28. 1947. Chicago Program.

The Economic Importance of Virus Diseases of Plants.—There are perhaps about 200 specific virus plant diseases now recognized throughout the world. Holmes (1939) and Hildebrand *et al.* (1942) list about 165 distinct virus diseases of which 70 occur in other countries. New ones are being recognized continuously and lead us to speculate how many are yet unrecognized. If we accept 100 as being endemic in the United States we may be justified in assuming that these diseases are as prevalent in other parts of the world. If this were true we can estimate on the basis of land ratios that there may be 1900 to 2000 virus plant diseases in other parts of the world, more than 95 per cent of which are not yet in the United States, but each of which might in time invade our borders and become established in some favorable environment. Not all of these are to be considered as highly dangerous but judging from our knowledge of those already studied we may assume that there are 1000 important plant viruses which are potential invaders of the United States, any one of which might be as destructive as the potato viruses, tobacco mosaic, aster yellows or peach yellows.

Knowledge of the destructive action of virus plant diseases is admittedly inaccurate in many cases but it may be of interest to cite a few references which are fairly typical. Conners & Saville (1944) reported the rejection for certification of potato fields in Canada from 1940 to 1944 caused by mosaic and leaf roll as follows. Mosaic 42, 28, 23, 19 and 11 per cent; leaf roll 17, 26, 36, 49 and 14 per cent. Swingle (1942) reported phloem necrosis of the elm as causing the death of 50 to 75 per cent of the elms in some towns and cities where it occurs in a broad band from eastern Iowa to western West Virginia.

The Plant Disease Reporter of the U. S. Department of Agriculture has recorded the estimated losses caused by various plant diseases over a considerable period of years. The losses due to virus diseases of the potato crop in the United States have been estimated to vary from 15 to 20 million bushels annually.

The virus diseases of stone fruits have

caused and are still causing large losses in the country. The economic history of peach yellows is a matter of historical record. Hundreds of valuable peach orchards have been destroyed by this virus. Today in the north central and northeastern United States the cherry yellows virus of sour cherries seriously affects as many as 90 per cent of the trees in some orchards (Hildebrand *et al.*). Raspberry culture in some regions has been abandoned because of the seriousness of the virus diseases of this crop. Scarcely a major cultivated crop is immune to this class of diseases today.

It is evident from the data available that the virus plant diseases are fully as destructive as many fungous and bacterial diseases, and new ones are being described with alarming frequency.

PHYSICAL CHARACTERISTICS OF VIRUS DISEASES.—Plant diseases are recognized or diagnosed by the effects they produce upon their hosts, commonly referred to as *symptoms*. In addition to symptoms the plant pathologist searches for the visible presence of associated organisms—the *signs* of disease. For example the blasted florets on a head of wheat is a symptom readily recognized. If the black powder made up of thousands of microscopic spores of *Ustilago tritici* are associated with the blasted heads the pathologist recognizes the sign and diagnoses the disease as loose smut. The diagnostician, therefore, has two definite aids for establishing the specific identity of fungous and bacterial disease—the *symptoms* produced, and the causal parasite or *sign*. In the absence of the sign his diagnosis is incomplete and often in question.

In contrast, the virus plant diseases present all the symptomatic types shown by fungous and bacterial plant diseases —hypoplastic (dwarfing), hyperplastic (swelling or enlargement) and necrotic (dying). To this extent virus diseases differ little or none at all from those diseases mentioned above. On the other hand they do not produce the visible signs so well recognized generally with the aid of the hand lens or the ordinary microscope as in the case of fungous and bacterial diseases. The virus entity is of such a nature that our present methods of recognition fail to reveal any visible sign that can be relied upon for diagnosis. This fact places the virus diseases in a special category from the diagnostic standpoint and makes the job of the inspector extremely difficult if not impossible to recognize any virus plant disease in dormant material by standard methods.

This lack of signs recognizable by established methods has posed a challenge to plant pathologists for a half century and led to studies by many scientists into the nature of plant viruses. A few of the outstanding characteristics should be mentioned.

The specific entity which we call a virus is of minute size, capable of passing filters which exclude bacteria. Such entities increase only in the presence of living cells, either plant or animal (insects chiefly in plant viruses) and may give rise to new strains by "mutation." They do not arise spontaneously (*de novo*). Their physical properties are variable. Most viruses are thermo-labile, few if any withstanding temperatures above 98° C. for 10 minutes. Many are inactivated by exposure at much lower temperatures (32 to 50° C.). They are more generally resistant to low temperatures, but some viruses are inactivated by freezing. The expressed juice from diseased plants of some of the mosaic types (*Marmor* spp.) has been purified in crystalline forms and found capable of transmitting the typical disease when inoculated into healthy suscepts. This feature had led some investigators to consider them as chemical in nature and ally them with enzymes. Others believe them to be essentially biological in nature—perhaps connecting the organic with the inorganic. The molecules of the purified crystalline viruses vary in size from that of the chemists' concepts to that of the smallest bacteria. Between this wide range many possibilities exist. To date we cannot positively say where they belong in the classification of the animate and inanimate worlds.

BIOLOGICAL RELATIONS OF PLANT VIRUSES.—The biological relationships are most interesting. An understanding of these is essential in any quarantine consideration. The enumeration of some of these biological relationships together with brief comments will be in place here.

The plant viruses are highly developed parasites, comparable in the scale of parasitism to the rust fungi. No plant virus has been multiplied outside the host cell (either insect or plant). The virus

entity present in the extracted juice from an infected plant or insect may be preserved for varying lengths of time under a favorable environment, but no increase takes place. Attenuation follows separation from the living cell. Infection results only when the active virus is inserted in a living susceptible cell under favorable conditions.

The host relations of plant viruses are again suggestive of those exhibited by the rust fungi. You are familiar with the life history of the black stem rust of cereals, *Puccinia graminis*. This parasite spends most of its life upon the small cereals and grasses where it is very destructive. In northern regions where the temperatures are too low for the vegetative stages of the fungus to live through the winter on grasses or cereals, the overwintering or resting spore stage (telium) cannot reinfect the graminicolous hosts but must infect the barberry, *Berberis* spp., if it is to survive. This condition involving an alternation between wholly unrelated hosts upon which different stages of the parasite are produced is known as *heteroecism*. By contrast a parasite like the flax rust, *Melampsora lini*, confines its entire life history to flax—a condition known as *autoecism*.

Some plant viruses present similar analogies. Aster yellows virus infects a large number of plants embracing several families upon which rather typical yellows symptoms appear but the eastern form of the virus under natural conditions apparently cannot be transmitted from one plant to another without first being ingested by one specific leaf-hopper, *Macrosteles divisus* (Uhl.)[2] after which the virus must incubate in this insect for about 2 weeks before it can be transmitted by the insect when feeding upon a susceptible host plant. The alternation of this virus between a susseptible plant and a specific insect is strangely analogous to heteroecism in the Uredinales (rust fungi). If viruses are to be considered as the most primitive type of parasite it may be permissible to suggest that this is further evidence that heteroecism is also a primitive condition. It is evident, therefore, that viruses of this type may be eliminated by complete control of the insect vector except in the case of propagation through budding, grafting, etc. Nearly 30 per cent of the viruses and seven of the 10 recognized virus families listed by Holmes (1929) belong in this category; that is, under natural conditions they are transmitted only by insects.

A much larger number of viruses belong to the three remaining families, Marmoraceae, Annulaceae and Acrogenaceae in which the diseases produced are quite readily transmitted to a susceptible host by means of artificially introducing the expressed juice from an infected plant. In some cases this may be accomplished by rubbing infected leaves between the fingers and then rubbing the leaves of a healthy plant as in the transmission of tobacco mosaic. Needle pricking and various abrasives are successful devices for transmitting many of this group of viruses. However, it is questionable whether under natural conditions any of these viruses would spread from one plant to another without insect transmission. Man has proved to be the most active agent in the spread of tobacco mosaic, and undoubtedly he can be blamed for the destructive spread of many other plant viruses.

Much of the above applies more particularly to the spreading of viruses in the vegetative stages of susceptible plants. Other reproductive parts may be capable of distributing the virus. Tubers, bulbs and in some few instances true seeds transmit viruses. Buds from infected plants will generally transmit the virus, and in numerous cases are the only successful method of artificial transmission. Cuttings are also effective means of distributing these diseases. They have been of the greatest important in the distribution of sugar cane viruses. Since these parts in their dormant stage are so commonly used in commercial propagation and, furthermore, because they invariably carry the virus without generally exhibiting any sign or symptom, they present a very difficult problem which is of great importance in quarantine considerations.

Mention should be made of those plant viruses which are readily transmitted by *many* insects—cucumber mosaic and potato spindle-tuber virus, the latter spread by aphids, grasshoppers, flea beetles, tarnished plant bug, larvae of Colorado potato beetle, and the leaf beetle *Disonycha triangularis*. This is an unusual case where both sucking and leaf-eating insects

[2] Formerly *Cicadula sexnotata*.

transmit the virus. The number of virus diseases known to be transmitted by leaf-eating insects is relatively small.

THE BASIS FOR A PROGRAM OF EFFECTIVE PROTECTION AGAINST VIRUS PLANT DISEASES.—The physical and biological features of plant viruses as briefly reviewed are fragmentary, lacking in many details and in need of much additional information of value, but they may suffice to form the background of a program for a more effective protection of our country against further invasion by plant viruses. Such a program must recognize the following points:

1. Phytopathogenic viruses are almost universally systemic and therefore any living portion of an infected plant may contain the active virus.

2. Virus diseases can be recognized visually with certainty only upon rapidly growing parts—foliage and flowers most commonly, proliferating buds in some cases (witches' brooms). The more mature tissues such as stems, roots, bulbs, tubers, corms, seeds, etc., do not, with a very few exceptions, exhibit symptoms of diagnostic value, but do carry the virus. Only 9 of the 129 plant viruses listed by Holmes (1929) are known to be transmitted through seeds.

3. Only the most easily transmitted viruses are spread by handling diseased plants or plant parts—examples: tobacco mosaic virus and possibly some legume mosaic viruses; potato spindle tuber virus is transmitted by the cutting knife.

4. Only a very few viruses are known to be capable of transmission through soil. Examples: tobacco mosaic virus; wheat mosaic virus; tobacco necrosis virus; anemone—alloiophylly virus.

5. Plant viruses appear to be confined largely to the seed-bearing plants (Spermatophyta), unless we admit the bacteriophages. Other groups like the gymnosperms, pteridophytes and bryophytes have not with certainty been shown to be hosts to viruses.

6. The introduction of virus plant diseases is not limited exclusively to living plants and plant materials. The insect vectors are capable of introducing the virus and adequate measures should be adopted to prevent such occurrence even though this channel of entrance to date has been unimportant. More rapid means of transportation may bring insect vectors into economic importance as wide disseminators of plant viruses.

7. Virus diseases, like fungous and bacterial diseases, are definitely limited in their geographical distribution by climatic factors which affect the virus directly or may affect it indirectly through its vector. Knowledge of the climatic conditions in the natural environment of any likely virus immigrant should be very helpful in predicting its possible course in this country.

8. The phytopathogenic viruses in countries outside the United States, Canada, Great Britain and Holland are very inadequately known and it may be assumed that they are present in numbers comparable to those already in this country. Special attention, therefore, should be given importations from countries and regions where plant viruses have not been studied extensively. This is of special significance in this post-war period when American plant scientists visiting foreign countries discover plants which appear to have a place in our economy and set in motion the steps necessary for their introduction.

9. Few plant pathologists outside of the four countries mentioned have the trained personnel available for the recognition of virus diseases. This applies also to fungous and bacterial diseases at the present time when phytopathogenic services are so generally disrupted in Europe and other parts of the world. Complete reliance must, therefore, be placed upon our own technical knowledge and sound restrictive organization if adequate safeguards against the further importation of destructive plant viruses are realized.

10. Certain vulnerable points appear in the life history of all parasites. This is axiomatic even though the weak spots are recognized today in only a limited number of the viruses. Among those already discovered are the viruses which are inactivated by high temperatures, various light effects, and chemicals. (Further comments regarding these inactivating agents are pertinent and are discussed later in this paper.)

11. An effective official organization is absolutely necessary to attain the desirable degree of virus disease exclusion. It is assumed that the United States Department of Agriculture has this organization through its Bureau of Entomology

and Plant Quarantine and that it has the legal authority in Public Law 290 to carry out any restrictive measures deemed essential in the interest of the national welfare.

12. The success of a plant quarantine agency in preventing the entrance into its homeland of any undesirable immigrant depends upon several factors, of which the following are of prime importance: an efficient cooperative administration willing and determined to resist all political and commercial pressures for the easement of special restrictions; a fully trained technical personnel of adequate size to do the necessary inspection at all points of entry; well equipped laboratories for the critical examination, by all known methods of any plants or plant materials under suspicion of carrying parasites of any sort; a sufficient number of detention farms and gardens, protected against the possible escape of parasitic pests, for the propagation of suspicious plants for a period long enough to determine their health condition; a complete file with indexes of all information available from every source, pertaining to virus diseases and other plant pests from every part of the world; and finally, sufficient funds to meet these requirements which are essential for the adequate protection of agriculture—America's most important industry.

All of the 12 points enumerated are essential parts of the knowledge and organization necessary for the effective prevention of the entrance of virus plant diseases. If such a system in action ever proves capable of detecting the often invisible viruses in plants and plant materials, it would be fully adequate to detect and bar from entrance any plant pathogen. It would be the highest type of quarantine effort attainable with our present knowledge.

Unfortunately, such perfection is unattainable, today. We are faced with the fact, insurmountable at present, that a large number of virus diseases cannot be detected, in the form in which they are normally presented for entry, by any method known today. Only when the imports bear foliage or other vegetative parts exhibiting unnatural symptoms is inspection of much practical value at present. However, during the past quarter century some success has been achieved in curing virus infections in certain cases by the various treatments already mentioned. The early successes with various therapeutic treatments are worthy of further consideration at this time.

THERAPEUTIC TREATMENT AND DETECTION OF PLANTS INFECTED WITH VIRUSES. —A. *Heat treatments.*—The cure of plants infected with viruses began in 1923 with the discovery by Wilbrink (1923) in Java that the sereh virus of sugar cane could be cured by immersing sugar cane seed pieces in water at 52° C. for 30 to 60 minutes without injury to the "seed."

Martin (1933–1934) in Hawaii published in 1934 his results on the treatment of sugar cane infected with the chlorotic-streak virus. He found that this virus was controlled by treating cuttings in water at 52° C. for 20 minutes.

Kunkel (1935) in 1935 reported the cure of peach trees infected with the yellows and the rosette viruses by holding them in a hot-room at 34.4° to 36.3° C. for 2 weeks or longer. Three weeks exposure at these temperatures did not injure the trees. The following year Kunkel (1936) reported complete inactivation of the yellows virus in year-old peach trees, with soil removed from their roots, by immersion in hot-water for 4 minutes at 50° C.; in 1 minute at 52° C. and in 15 seconds at 56° C. or longer. Yellows diseased buds were cured by hot-water treatment for 25 minutes at 45° C. and in 4 minutes or longer at 50° C.

In the same paper Kunkel reported the cure of peach buds infected with the little peach virus by immersion in a hot-water bath for 115 minutes at 40° C.; for 20 minutes at 46°; for 8 minutes at 48°; for 3 minutes at 50° and for 30 seconds at 52° and above. The virus in peach buds infected with rosette was completely inactivated by exposure in hot-water for 10 minutes at 50° C. However, peach rosette is not cured by this method in trees which are completely diseased since such trees become very susceptible to heat treatments. Another virus disease of the peach known as red-suture is cured in peach buds by treatment in hot water for 3 minutes at 50° C. Failure to cure the peach mosaic virus by heat treatments which were not injurious to the host was reported by Kunkel (1936) in 1936. Again of special interest were the experiments of Kunkel (1937) who succeeded in inactivat-

ing the virus of aster yellows in the insect vector, *Cicadula sexnotata*. He found that the exposure of viruliferous leafhoppers for 12 days in a room kept at 32° C. was sufficient to kill the virus. This lethal temperature for the virus in the insect is considerably lower than that required to inactivate the virus in a treatable plant infected with the same virus. This fact may indicate that this virus undergoes some change during incubation in the insect vector, during which it becomes more sensitive to thermal treatments. Or it may be that the difference is due to the small size of the insect thus enabling the heat to reach the virus more rapidly. However, Kunkel (1939) showed that the virus was killed more readily during its incubation period in the leafhopper than after this period when the insect had become infective.

Hutchins & Rue (1939) working on the control of the phony-peach virus, which is confined to the roots of its host, were able to inactivate the virus by immersing 2-year-old infected trees in hot water for 40 minutes or longer at 48° C. Such treated trees remained healthy for 20 months and were considered cured.

Hildebrand (1941) in 1941 demonstrated that the X or yellow-red virus of peach trees was inactivated in bud sticks held for six minutes or more in a hot water bath at 50° C.

Kunkel (1941) was unable to cure yellows in asters without serious injury to the plants, but when the aster yellows virus was transmitted to the periwinkle, *Vinca rosea*, by infective leafhoppers he was able to inactivate the virus in Vinca by exposing the infected plants in rooms held at 38° and 42° for 2 weeks. Infected periwinkles were also cured by a 3-hour-immersion in hot water at 45° but some injury to the plants resulted, from which, however, they later recovered. It is to be noted again that only 12 days dry heat exposure of the viruliferous vector, *Macrosteles divisus* at 32° is necessary to inactivate aster yellows virus, while 14 days exposure is required to inactivate the virus in infected plants at a minimum of 38°.

Most herbaceous plants appear to be too sensitive to heat for such therapeutic treatment but *Nicotiana rustica* (turkish tobacco) may be freed successfully from the aster yellows virus by dry heat treatment for 3 weeks at 40° without serious injury. Similar attempts with infected lettuce plants failed because of severe injury to the host.

In 1942 Kunkel (1942) reported the cure of cranberry false-blossom virus in *Vinca rosea* after the virus had been transmitted to this host from cranberry by means of dodder, *Cuscuta campestris*. The virus was readily killed in *Vinca* by exposure in a hot room for 2 weeks at 40° C.

Potato witches broom virus was also transmitted by dodder to *Vinca rosea*. The periwinkles thus infected were cured of witches broom disease by treating them for 13 days or longer in a room held at 42° C. Kunkel (1943) was also able to cure the witches broom virus in small potato tubers by exposure in a room at 36° C. for 6 days.

Further studies reported by Kunkel (1945) in 1945 proved that false-blossom virus of cranberry could be transmitted to 28 different species of plants in 10 families by means of dodder. He presented some evidence that the virus multiplied in the dodder. Successful cure of this virus was secured in the natural cranberry host by treating diseased plants at 42°–43° C. in a hot room for 8 days. Mercuric chloride in sufficient concentrations and at pH values greater than 6.0 causes loss of infectivity as well as serological activity according to Kassaris & Kleczkowski (1944).

Millard (1945) in 1945 reported killing a mosaic virus carried in the seeds of broccoli by heating them for 25 minutes at 122° F. (50° C.).

The 12 distinct viruses which have been shown to be inactivated by heat in their living hosts is sufficiently impressive to indicate the great need for further studies with both dry heat and hot water treatments. It has been fully demonstrated that the critical temperature for the inactivation of these viruses *in vivo* is inversely proportional to the time of exposure. This indicates that much longer exposures should be attempted with those viruses which infect plants which are sensitive to high temperatures but which will withstand long exposures at temperatures to which the virus may become inactivated over long periods. The most likely successes should be with perennial plants whose tissues are less sensitive to heat.

B. *Light effects.*—The effect of sunlight on tobacco mosaic virus was reported in 1926 by Mulvania (1926) who found that the longer the exposure the lower the infectivity after the first 12 hours. An exposure for 36 hours reduced infectivity to 10 per cent. He found also that exposure of the filtered virus under a mercury vapor lamp at 6 inch distance for 1 hour or more inactivated the virus. Treatments of the virus with x-rays up to 30 minutes had no measurable effect upon its infectivity.

Smith (1926) reported that short wave ultra-violet light inactivated filtered tobacco mosaic virus *in vitro* in 30 minutes exposure, while diseased plants exposed to longer rays masked the symptoms and dwarfed the plants after 18 days exposure. Two of the four plants surviving this treatment were apparently healthy 40 days after the exposure.

Arthur & Newell (1929) reported the inactivation of tobacco mosaic virus by 15 seconds exposure *in vitro* to the open arc mercury lamp if contaminating material is removed from the virus. Inactivation *in vivo* failed at any exposure to which the host was not severely injured.

Stanley (1936) recorded the inactivation of crystalline tobacco mosaic virus by ultra-violet light in 1936 and Bawden & Pirie (1937–1938) reported the complete loss of infectivity of potato X-virus and tobacco mosaic virus by x-rays and ultra-violet light.

Price & Gowen (1937) found that filtered tobacco mosaic virus, solutions of this crystalline virus, and the crystalline mosaic protein plus juice from healthy plants were completely inactivated by exposure for 200 minutes or more in watch glasses under a mercury lamp at a distance of 7.5 inches with the temperature kept between 20° and 24° C.

The influence of exposing tobacco plants infected with tobacco necrosis virus, *Nicotiana glutinosa* and tomatoes infected with bushy stunt virus, *N. glutinosa* and tobacco plants infected with tomato acuba mosaic virus to various sunlight intensities was studied by Bawden & Roberts (1947) who found that decreasing the exposure to one-third less sunlight increased the susceptibility to infection more than ten times in the case of the first two viruses and more than 5 times in case of the second two. Decreasing the sunlight also increased materially the virus content of sap in the leaves.

It appears that filtered viruses are readily inactivated by ultra-violet light but attempts to inactivate the virus *in vivo* have not been entirely successful, although Miss Smith (1926) apparently secured a complete cure of a few infected plants. This indicates that more research with various light intensities and wave lengths should be pursued. It is also evident that sunlight exerts a strong influence on viruses—the greater intensities and exposures reduce their infectivity to a marked degree in infected plants. It is well known that certain viruses are masked under conditions suggestive of light effects. It should be interesting to pursue this phenomenon further by studying the effects upon virus infected plants transferred to areas of greater natural light intensities such as exist in arctic regions, in contrast with longer exposures to artificial light intensities of various wave lengths.

C. *Chemotherapeutic effects and chemical inactivation.*—The effects of organic and inorganic chemicals upon viruses *in vitro* have been studied for many years. The more recent investigations have indicated some practical applications of chemical tests for the detection and inactivation of certain viruses which are noteworthy.

Stanley (1936) reported in 1936 the inactivation of the crystalline tobacco mosaic virus by hydrogen peroxide, formaldehyde and nitrous acid, but Ross & Stanley (1938) later found that the formalized virus could be partially reactivated by dialysis at pH 3.00.

Bawden & Pirie (1938), reported the inactivation of tobacco mosaic virus, potato-X virus, and bushy stunt of tomato virus by nitrous acid; also the above three viruses and tobacco necrosis with urea, (Bawden & Pirie 1940).

Stoddard (1942) reported inactivation of the X-disease virus of peach by soaking diseased peach buds in urea, calcium-8-hydroxyquinolate, magnesium 8-hydroxyquinolate, o-nitrophenol, and sodium thiosulphate. The treated buds remained healthy for 2 years after treatment.

Stoddard (1944) reported encouraging results in the control of peach-X-disease virus by the injection of chemicals in the cut stems. These studies indicate the need for detailed investigation of the effects of many chemicals upon viruses *intro vito.*

With improved techniques for the injection of chemicals into living plants without producing injurious effects, it seems probable that cures will be found for many viruses, as well as for bacterial and fungous plant diseases.

D. *Methods of detection in living tissues.*—Hutchins (1933) reported the first chemical color reaction for the detection of a virus disease—the phony-peach disease. Transverse fresh sections of diseased peach roots exposed for a few minutes in absolute methyl alcohol acidulated with hydrochloric acid produces distinct purplish spots in the woody cylinder where the virus is located. This test has been widely used in 13 states with reliable results for the detection of phony peach virus in nursery stock and field plantings.

Quirk (1939) has reported a rapid reagent indicator color test for the detection of tobacco mosaic virus, in the tobacco plant, which is parallel to the pH method for testing the H-ion concentration of plant tissues.

Rawlins & Thomas (1941) reported that the buckskin disease virus of cherry in California could be detected by the red color of the affected cells between the phloem rays when sections were treated with phloroglucinol in 18 per cent hydrochloric acid. The disease is detected by this method in both peach and cherry.

Simonds & Bodine (1943) working with peach mosaic in Colorado found that the virus in diseased peach roots and stems could be detected by color reaction in the xylem through exposure of thin sections to a saturated solution of phloroglucinol in absolute methyl alcohol followed after evaporation, by treatment with nitrophenolic acid in methyl alcohol.

E. *Sound effects.*—Takahashi, & Christensen, (1934) reported the inactivation of tobacco mosaic virus by exposing it to high frequency sound radiation for varying periods. No infection was obtained by injection of the treated virus into healthy tobacco plants after treatment for two hours at 450,000 cycles per second. This work seems to be the only recorded case of the use of high frequency sound radiation on plant viruses. The results suggest a fertile field for further research.

CONCLUSION.—The plant diseases caused by viruses are of great importance in reducing the production of valuable plants and plant products. They are fully as destructive to some crops as are the better known fungous and bacterial diseases. They are more dangerous from the quarantine standpoint than any other class of diseases because of their peculiar nature—namely, their inability to be detected in dormant plant parts by any of the usual methods successful in detecting fungi, bacteria and other parasites and pests.

Hundreds of potentially dangerous plant viruses undoubtedly exist without our borders and every possible action should be taken to prevent their entrance into the United States. Much more effective precautions than hitherto in force should be taken at once.

Some promise in the detection of viruses in plant imports has been outlined and should be actively followed up with further researches. Of special promise are the cures of several virus diseases in living plants and plant parts which have been demonstrated as quite practical. Further active research in the field of heat and light treatments, as well as in chemotherapic research, is indicated. No possible avenue of approach to the ready detection of virus diseases should be overlooked. Who can say what might result from research in the effects of radio-active isotopes on plant viruses? It is an open and challenging field for the highly trained plant pathologist. These are efforts for the future.

Today we must realize that the Utopian State may be a long way off. We cannot afford to mark time while research solves the problem. The danger is immediate. Complete exclusion of all flowering plants and their propagative parts would be the most effective solution, but wholly impractical and undesirable under present world situations. Courses must be pursued which have a practical application with our present knowledge of the virus disease problem and the needs for further plant imports. Much extremely valuable information could be secured by sending phytopathologists trained in this field to those countries from which new plants and plant products are seeking admittance. This approach has been emphasized many times in past years by the Committee on Foreign Plant Diseases of the American Phytopathological Society, 1928 to 1940. It is still a valid approach through the Department of State.

Of greater immediate value would be the expansion of detention stations within our borders. Several have been established but they are still very inadequate to meet the present and future needs. Their limitations were outlined by Rohwer (1941) at the Dallas meeting of the American Phytopathological Society, December 29, 1941. They should be located with consideration to climatic and soil conditions as well as to isolation safeguards. Adequately staffed and of ample size, such detention centers for the propagation and growth of plant immigrants until their health conditions can be determined probably offer the best practical protection for the present. Surely the protection of our agriculture against further introduction of destructive plant diseases is worth many times the cost of maintaining adequate detention centers.

The last paragraph in the excellent discussion by McCubbin (1942) on "Preventing Plant Disease Introductions," states in fully adequate language the position which your present speaker believes should be adopted in America. "They, (national thinkers) reason that, naturally protected behind effective continental barriers, any powerful and civilized people ought to be able to control its imports in such a way as to exclude undesirable plant parasites quite as successfully as it strives to do in the case of many dangerous human and animal parasites; that even the far-from-perfect functioning of recently established quarantine systems has apparently been successful in preventing or delaying for many years the introduction of various pernicious pathogens; and that a fuller realization of the cost and consequences of pest introduction will in time inspire a widespread popular demand throughout the world for better protection against introduced pests and create support for more stringent exclusion measures as a course definitely in the national interest. They believe that rapidly increasing knowledge, improved technical methods, and greater experience in administrative procedure are likely to assure for the future a standard of quarantine accomplishment now undreamed of, and that the extraordinary past achievements of human society in its age-old struggle to control and subjugate the natural world to its own will and purpose distinctly encourages hope for the ultimate success of a national effort to exclude injurious foreign plant pathogens."

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THE INSECTS OF MONA ISLAND (WEST INDIES), by J.A. Ramos (Jour. Agr. Univ. P. R., **30**(1): 1–74, pl. 2, ref. 45. January 1946, actual date of publication, December 31, 1947).

Christopher Columbus sighted Mona Island in 1493 and landed there in 1494, as later did also Sir Walter Raleigh's colonists en route to North Carolina. Ponce de Leon provisioned there before attempting the colonization of Puerto Rico, for Indians permanently inhabited Mona at that time, and cultivated ground crops. Early in the 19th century, the locally known pirate, Cofresi, made his headquarters on Mona. Shortly before First World War, a German company had a concession for the exploitation of the guano resources of its bat caves, and from this period date the earliest published records on insects: the Elaterid *Adelocera rubida* Schwarz (1902) and the Phasmid *Lamponius bocki* Brunner & Redtenbacher (1908). In 1913, R. H. Van Zwaluwenburg and E. G. Smyth brought back the first specimens of that striking, iridescent green and red or orange Coreid: *Spictyrtus whitei* Guérin-Méneville, rare in Cuba and the Bahamas, of which adults are normally so common on Mona. Dr. Frank E. Lutz, of the American Museum of Natural History, collected intensively there, February 21–26, 1914, and subsequently numerous entomologists from Puerto Rico have added extensively to these records, when observing the status of such economic forms as cottony cushion scale, pink bollworm, onion thrips and moth-borer of sugar-cane. With notes on their distribution, abundance and host plants, Prof. J. A. Ramos records a total of 526 species of insects from Mona, of which 197 were not previously known to occur there, while 24, or 4.56 per cent, are endemic, occurring nowhere else. He describes four new species of Hemiptera-Homoptera and includes a description by Dr. W. T. M. Forbes of a new Geometrid: *Ptychopoda monata*. "The paucity of the insect fauna of Mona Island is probably due not only to the small area of the island, but also to the extremely arid condition and scant vegetation of the region."—G. N. WOLCOTT.

Toxicity of Some of the Newer Chemicals to the Honeybee

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The honeybee adds materially to our agricultural wealth by its service in pollinating a majority of the fruit, vegetable and seed crops. The beekeeping industry provides the colonies of bees to effect these pollinating services. For these reasons, any substantial loss of bees generally causes concern to the growers of those crops that are benefited by bees as well as to the owner of the colonies themselves. The increased use of agricultural chemicals in recent years, and especially those in dust form which are toxic to bees, has created a definite hazard to beekeeping. When poisons are applied at such times or in such quantities as to kill many colonies of honeybees, it seems obvious that the same poisons also will kill many of our native pollinators, such as the solitary bees and bumblebees. It is therefore important to determine the probable effect the new chemicals might have on honeybees and other beneficial insects.

For many years the arsenicals were the chief cause of worry for the beekeeper and the farmer who appreciated the value of honeybees. Arsenicals applied to plants in bloom, either in the dust form or as liquids, or where the dusts are allowed to drift over miles of land adjacent to fields treated, have destroyed thousands of colonies of honeybees. In order to control many of the injurious insects, arsenicals have to be applied in such heavy concentrations that they can now be classified as comparatively inefficient insecticides. The need for using such large quantities of arsenicals to effect control also increases the hazards to bees, livestock and other agricultural interests. It would appear then, that the time is most opportune to eliminate the arsenicals from all pest control programs and to substitute some of the newer chemicals when they are less hazardous to beneficial insects and give give as good or better control when used in smaller quantities. Consideration should be given to the probable toxicity of the newer chemicals to bees when they are incorporated into control programs.

Our experiences with DDT have indicated that it is not nearly as injurious to bees as the arsenicals when applied to different crops. DDT, like some other of the newer chemicals, acts not only as a stomach poison to bees but also as a contact insecticide. Although bees do not, on the whole, crawl over leaves and stems of plants when they gather pollen and nectar, they do become covered with dust while working in a freshly dusted field. When the DDT dust is applied in sufficient concentration to get a lethal amount on the bee or in the nectar of different flowers, injury to the parent colony will result. In some cases injury from DDT has resulted in a marked reduction of the field force but no case has come to the writer's attention of where colonies thus injured have been killed.

The difference in the effect on bees between DDT and arsenic appears to lie in the fact that only a small amount of DDT need be applied to give as good or better results than the larger dosages of arsenicals required. When one spreads on each application only 1.5 pounds of DDT over an acre of tomatoes, in contrast to 21 pounds of calcium arsenate, the hazards of drifting poisons are immediately reduced. It seems probable that if only 1.5 pounds of calcium arsenate per acre would be sufficient to give economic results, the loss of bees and injury to livestock might be no greater than has been indicated for DDT. The same principle may apply to other poisons which need be used in no larger dosages than DDT if a comparable toxicity is indicated for each under laboratory conditions. This might not be true for any chemical that is toxic to bees as a fumigant as well as through contact and ingestion.

Laboratory Methods.—Bees are taken from the top story of a hive, usually in the morning, and without smoking the colony and placed either in individual 2- or 3-hole queen cages of 4 by 5 by 0.75 inch cages. The larger cage has a screen fastened to the bottom and a sliding screen on the top. Approximately 30 to 40 bees are placed in each of the 4 by 5 cages for each test. The individual cages are fitted with queen cell cups to hold sugar sirup. The individual bees are fed from a micropipette a known concentration of the chemical being tested in 20 per cent sugar sirup and groups of 10 or more

bees are given .01, .015, .02 or .025 ml. at a feeding. Soon after the feeding, the queen cell cups are filled with 20 per cent sugar sirup and the cages are kept at a laboratory temperature between 70 and 80° F., although in summer the temperature may be higher. Bees in the larger cages are fed concentrations of the chemicals in 20 per cent sugar sirup from inverted vials covered with paraffined paper with a small hole in each center.

To check the apparent reaction of bees on contact with the different poisons, bees are either dusted or sprayed through the wires of the cage, or are permitted to walk on a treated surface; or a cage is sprayed and allowed to dry before the bees are inserted. In checking the fumigant action of a chemical, bees are placed in a second cage above the one that has been sprayed but so the bees do not come in contact with the treated cage.

Check bees are placed in like cages and fed in a similar manner. Observations are carried over a period of a week but results, unless otherwise stated, are based on a period of not more than three days in order to reduce the error of death from natural causes.

In addition, observations are made on colonies of bees located in the vicinity of sprayed or dusted fields. Beekeepers are also encouraged to cooperate in making the latter observations and to report any evidence of injury to their colonies. Since bees are known to work over a large area and not necessarily in the nearest fields, observations in the field must be screened very carefully in order to eliminate the possibilities of bees not working in the fields treated or in getting poisons from other sources.

Laboratory tests are not entirely reliable because some bees obviously recover from the effects of certain poisons when they would surely die if affected in the same manner in the field and exposed to the natural environmental conditions. Also, bees that are stricken with certain poisons while in the hive are known to leave the hive and soon die when exposed to the sun, ants, and other elements, whereas in the protection of a cage, they may recover or at least live for several days. Cage tests may indicate that certain chemicals may shorten the natural life of bees but not kill them within a 2 or 3 day period.

METHODS OF MAKING DILUTIONS.—As a general rule, each chemical was dissolved in either water, acetone or 95 per cent alcohol. The solutions were handled at room temperatures without allowance being made for the slight changes that occur in volume or in the capacity of the glassware due to changes in room temperature. Solutions were made to contain not more than 2 per cent of either acetone or alcohol as bees were tolerant to this percentage for the length of the observations. Solutions or suspensions were made just before being fed to the bees and great care was used to prevent either the contamination of the cages or of the glassware. A 20-per cent solution of sugar in distilled water is preferred to a heavier concentration because of the smaller error resulting from the adherence of the sirup to the small bore of a micropipette. Alcohol was used as a solvent in most cases because it gave a better dispersion of the hydrocarbons in sugar sirup.

EXPERIMENTAL RESULTS.—*Hexaethyl Tetraphosphate.*—A sample containing 3 per cent of hexaethyl tetraphosphate dust killed 31 per cent of the bees in 48 hours when dusted on the bees through the wire of their cage. The bees became agitated, rapidly cleaned their bodies with their feet and fanned the dust from the cage.

A sample of 50 per cent hexaethyl tetraphosphate in ethyl acetate when diluted with 20 per cent sugar sirup killed 71 per cent of the bees at a dilution of 1 to 12,800 in 48 hours. A dilution of 1 to 25,600 killed only 25 per cent of the bees in 48 hours.

Two samples of 100 per cent hexaethyl tetraphosphate were obtained and used in more extensive tests. The L/D-50 fell between .24 and .34 microgram per bee. Under field conditions, this L/D-50 would be somewhat lower because the bees were definitely incapacitated for a few hours after being fed smaller amounts but recovered in the protection of their cages. A dilution of 1 to 200,000 killed 65 per cent of caged bees within 48 hours.

Loss of toxicity of the solutions was in direct relation to their dilutions. A concentration of 1 to 800 killed 64 per cent of caged bees after the solution was 3 days old, whereas it killed all bees within 2 hours when freshly made. A dilution of 1 to 48,000 killed all bees within 8 hours but only 50 per cent of the bees after

standing 24 hours. A dilution of 1 to 200,000 killed 65 per cent of the caged bees the first 24 hours, but none of a fresh lot of bees after being made for 24 hours.

Tetraethyl Pyrophosphate.—A series of dilutions ranging from 1 to 1000 to 1 to 2,000,000 were fed to caged bees while individual bees were fed varying quantities of the chemical. All dilutions were made in 20 per cent sugar sirup. The L/D-50 was .075 microgram per bee. A dilution of 1 to 1,000,000 killed 90 per cent of caged bees in 48 hours and 1 to 1,500,000 killed 43 per cent in 24 hours.

Tetraethyl pyrophosphate has considerable toxicity to bees as a contact poison for a period of two days at a concentration of 1 to 800. In checking this factor, a 4×5×0.75 inch cage was sprayed with an aqueous solution of tetraethyl pyrophosphate, 1 to 800, and allowed to dry. Bees were killed in this cage when inserted at intervals over 48 hours.

The tetraethyl pyrophosphate solutions lost their toxicity in a manner similar to the hexaethyl tetraphosphate solutions. A dilution of 1 to 512,000 killed 100 per cent of the bees when newly made but only 10 per cent of a fresh lot of bees the following 24 hours.

2,2-bis (p-chlorophenyl)-1,1-dichloroethane, $(ClC_6H_4)2HCCHCL_2$.—A stock solution was made by dissolving .5 gram of the chemical in 19.5 grams of 95 per cent alcohol. Dilutions containing known quantities by weight, were fed to individual bees with the results given in table 1. The data indicate that the L/D-50 was approximately 16 micrograms per bee. This amount would be contained in about one-third of a bee load of a dilution of 1–1040 of 20 per cent sugar sirup, and indicated a rather low toxicity of the chemical for the honeybee in comparison with the other hydrocarbons. A concentration above 1 to 5000 would seem to be comparatively non-toxic to bees.

Table 1.—Results of feeding 2,2 bis(p-chlorophenyl)-1,1-dichloroethane in 20 per cent sugar sirup to individual bees.

No. of Bees	Volume Fed Ml.	Weight Fed Mg.	Per Cent Dead in Hours 12	24	48	72
30	.01	10.4	6	6	6	6
41	.01	12.5	12	14	24	24
56	.015	15.6	10	16	16	18
10	.01	16.6	40	50	50	60
40	.015	18.7	62	62	62	62
64	.02	20.8	33	46	50	51
20	.02	24.0	85	85	85	85
60	.02	25.0	68	71	73	73
15	.025	26.0	20	46	53	53
20	.025	33.2	95	75	100	
10	.03	38.0	100			
10	.03	49.8	100			

When a cage was sprayed with a 5 per cent solution in acetone, and allowed to dry, bees were killed by contact with the cage for at least 4 weeks. All bees placed in the cage on the day it was sprayed died within 2 hours but many lived for approximately 48 hours on each test during the next 3 weeks.

Chlordan.—This hydrocarbon, is highly toxic to honeybees on contact, and as a stomach poison. It has considerable fumigant action as well.

When a 3.1 per cent chlordan dust was sprinkled lightly on a piece of waxed paper and placed in a 4 by 5 by 0.75 inch cage of 30 bees, the bees began to run and tumble almost immediately, became incapacitated in from 3 to 4 hours and thereafter exhibited no coordinated movements. They died in 7 to 8 hours. When additional bees were placed in the same cage, without renewing the dust on the waxed paper, all died within 24 hours. This procedure was repeated on successive days, without renewing the dust and after all visible traces of the dust had been removed by the various lots of bees, with the same results for 5 days, indicating a high residual action of the dust to bees.

A 3 by 4 inch piece of waxed paper was sprayed with a 5 per cent solution of chlordan in acetone, and allowed to dry. Bees placed in this cage died within 3 hours on each of several trials. When exposed to the paper for 10 minutes and then placed in an uncontaminated cage, the bees died within 24 hours.

A cage of bees was then placed above the cage containing the paper sprayed with a 5 per cent solution of chlordan in acetone but without the bees coming in contact with the cage below. All bees became incapacitated within 3 hours after exhibiting all of the symptoms of bees affected with chlordan poisoning.

The walls of a room, approximately 10 by 12 by 8 feet, were sprayed with a 5 per cent wettable chlordan spray as a remedy for the Argentine ant.[1] After

[1] Chlordan as a dust was found to be definitely repellant to the Argentine ant for a considerable period of time, which is not in accord with some published statements. It makes an excellent barrier around their nests or when sprayed on the walls of a building or foundation of a house. Ants that come in contact

the spray had dried, the room was warmed up to 70° F. and two cages of bees, supplied with sugar sirup, were placed in the center of the room and about 4 feet above the floor. The cages were covered over with hoods to prevent any dust that might flake off the ceiling from dropping on the cages. The bees became affected in 3 hours and all were moribund in 6 hours.

Two brood combs were placed in the comb room two weeks after it had been sprayed and were left in the room for two weeks. When placed in nucleus hives of bees, all bees died in the two hives within 48 hours.

A 4 by 5 by 0.75 cage was sprayed with a 5 per cent solution of chlordan in acetone and allowed to dry in the sun. This cage killed all bees placed in it at intervals between September 22 and December 5, the time for the kill varying from 2 hours at first to 9 hours on the last trial. The cage was kept on a laboratory table during the period.

When chlordan was fed to bees in a 20 per cent sugar sirup, the L/D-50 was approximately 1 microgram per bee. Sirup containing .8 microgram of chlordan per bee was practically non-toxic while 1.21 micrograms per bee killed 60 per cent in 3 days, 1.61 micrograms killed 81 per cent and 2.41 micrograms killed 95 per cent in 3 days. Strangely enough, some of the bees affected apparently recovered sufficiently to live for a week even though during the time, they frequently tumbled about in the cages. Under normal conditions, an amount somewhat less than 1 microgram per bee might prove fatal because the bees are visibly affected by lesser amounts and would be subjected to additional destructive forces, such as the heat of the sun, dust and insects as well as starvation.

The bees showed no dislike for chlordan when it was dissolved in acetone or alcohol and then mixed with 20 per cent sugar sirup in any of the concentrations used. The bees were immediately agitated by the dust when they came in contact with it and ran wildly within a few minutes after they came in contact with the sprayed cage or papers.

Parathion is a new chemical on the American market, still in the experimental stage. This chemical appears to be the most toxic compound to bees that the writer has observed. Twenty bees were placed in one of the 4 by 5 cages containing a waxed paper lightly dusted with a 2 per cent parathion dust. The bees ran wildly and brushed their tongues and bodies as soon as they came in contact with the dust. Two bees started to fight and one was killed. All bees were moribund within 25 to 30 minutes on each of several tests.

A cage of 30 bees was then placed over one containing a lightly dusted paper, but not in contact with the lower cage. The bees began to run wildly within an hour and all were moribund within 3 hours. As it was possible that the bees may have fanned some of the dust onto their bodies, a cage was sprayed with 1 per cent solution of parathion in 95 per cent alcohol and allowed to dry in the sun for 3 hours. This was done on November 25 and at intervals between then and December 6, all bees died in cages placed above the sprayed cage, the bees becoming moribund in from 1 to 8 hours. When two cages were placed on top of the sprayed cage, the bees in both cages died in from 3.5 to 6.5 hours.

Bees placed in the sprayed cage for one minute and then removed to an uncontaminated cage, were moribund within an hour. Bees left in the sprayed cage were moribund within 20 minutes. This time gradually lengthened until it took 3 hours for the bees to die 10 days after the cage was sprayed.

When dissolved in 95 per cent alcohol and then mixed with 20 per cent sugar sirup, the L/D-50 was approximately .07 microgram per bee. A feeding of 0.63 microgram per bee killed 25 per cent of the bees while a .078 microgram per bee killed 95 per cent within three days. A majority of the bees were killed within 12 hours and of those that survived, most of them lived for a week or more. As with the other phosphates, the effect of the minimum dose was such that many of the bees that survived in the cages would have died under normal conditions.

CONCLUSIONS.—These observations indicate that the phosphates, including hexaethyl tetraphosphate, tetraethyl pyrophosphate, and parathion are toxic to bees in minute quantities and will incapacitate bees for a few hours in quanti-

with the dust immediately withdraw and the ants soon disappear from that immediate area.

ties that are less than the indicated L/D-50 amounts. The phosphates are injurious to bees as contact insecticides and as stomach poisons. Parathion also exhibits considerable toxicity to bees as a fumigant.

Dichloro-diphenyl-dichloroethane on the other hand, is less toxic than any of the hydrocarbons and would apparently be non-toxic in dilutions above 1 to 5000.

Chlordan is highly toxic to bees as a stomach poison, contact insecticide and as a fumigant. The approximate L/D-50 is 1 microgram per bee. The residual action extends over a period of 3 or more weeks under laboratory conditions.

Neither the phosphates nor the hydrocarbons have any repellant action to bees when dissolved in sugar sirup or when sprayed on surfaces over which the bees walk.

Due to the small amounts of the phosphates and hydrocarbons that are required to be applied to give economic control of injurious insects, it would seem highly probable that neither the phosphates nor the hydrocarbons will be as injurious to bees as are the arsenicals. One would be in error to say that the hydrocarbons are not toxic to bees without qualifying the conditions under which the specific observations were made or the conditions under which the materials are applied. The loss of toxicity of the phosphates in a relatively short time, is another factor that will mitigate against the loss of bees when the chemicals are properly applied. However, it should be obvious from the laboratory tests that loss of bees will result if the newer chemicals are applied in such amounts or at such times as to permit the bees to secure, either through contact, fumigant action or by ingestion, the amounts indicated as lethal.

Due to the great value of all pollinating insects, those recommending or using poisons for the control of injurious insects should take this value in consideration and should do everything possible to prevent unnecessary hazards. Thus, it would be desirable to confine insecticides to the fields treated; they should not be applied to plants in bloom unless absolutely necessary, and the chemical that is least toxic to beneficial insects should be used.[1]

[1]The author gratefully acknowledges the cooperation of the companies supplying the technical grade of materials used in these tests.

The Use of Sodium Sulfathiazole in the Treatment of American Foulbrood Disease of Honeybees

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Our observations on the use of sodium sulfathiazole in the treatment of American foulbrood, started in 1945, were continued with 19 of the colonies mentioned in the previous report (Eckert 1947) together with 18 additional colonies secured from other sources. The investigations included the analyses of bees, larvae, royal jelly, honey and sugar sirup ripened by bees and the treatment of infected colonies with sulfathiazole added to honey extracted from their combs. In all, a total of 37 colonies were under observation in 1947 and are included in this report.

COLONIES ORIGINALLY TREATED IN 1945 AND 1946.—The original 19 colonies treated previously, wintered in good condition and all were apparently free of disease during the spring of 1947 and until midsummer when Colony *S-9* was found to be infected. The infection was in a shallow super of combs that had been added to give the colony additional food reserves. The re-infection obviously had come from this super. This colony had been made by dividing a diseased colony in April, 1946 and had shown no evidence of disease in the following 16 months. A second colony, *S-18* remained free of disease until August, 1947, when many cells

[1] In our experiments with sulfathiazole we deem it desirable to use a honey extractor used only for extracting combs from diseased colonies in order to prevent the contamination of other combs. There is danger of spreading the disease in the honey house unless this precaution is taken.

Acknowledgment is accorded to Mr. H. W. Allinger for the analyses of samples made under the supervision of Dr. H. A. Young and Dr. H. G. Reiber of the Chemistry Division, University of California, Davis.

of disease were found scattered in 8 combs. This colony had shown no symptoms of disease for the preceding 12 months and had reared brood in the combs of both stories. Five pounds of bees had been shaken from it in April to make up nuclei. The infection may have been a recurrence although it developed fast and in a very short time. Both colonies were treated immediately by being fed a 1 to 3 mixture of water and honey with the addition of sodium sulfathiazole. The honey had been extracted from the two colonies. The bees were gathering nectar at the time so the amount of the sulfathiazole was increased to one-half gram for each 5-pound tin of honey-sirup or twice the amount usually required. A total of 6.25 grams of sodium sulfathiazole were fed to Colony *S-9* and 6 grams to *S-18*. Colony *S-9* cleaned up the disease and gained in strength during the next 4 weeks and appeared to be free of disease when last examined on October 1. Colony *S-18* gradually weakened in number of bees and brood and the queen stopped laying entirely by the first week in September, when the bees covered only 10 combs. The colony was then reduced to one story. In the belief that Colony *S-18* was queenless, a new queen was introduced in a cage but she was killed. A week later another queen was introduced by the syrup method. Two weeks later, two queens were found to be present and the old or original queen was removed. The young queen had established a small brood area in two combs. Her brood was free of disease although many scales were present in the same combs as well as in 6 of the other combs. The old queen had apparently been injured by the sulfathiazole concentration and the young queen did not expand the brood areas as much as it seemed possible, probably from the same cause. The bees covered only 4 frames by the last of October and had healthy brood in 2 combs, with many scales still present in other combs. The queen was then killed and the combs and bees united with another colony, *S-22*, in order to check on the remote possibility that the strain of bacteria in the combs might have resistance to sulfathiazole.

Colony *S-22* had been used as a check to determine if it would develop disease when fed honey extracted from *S-9* and *S-18* after they had become diseased. The honey fed to *S-22* was diluted 1 part of water to three of honey with 0.5 gram of sodium sulfathiazole added to each 5-pound tin of honey-sirup. The colony did not develop American foulbrood during two months of observations.

During the spring and early summer of 1947 seven additional colonies, variously infected with American foulbrood, were acquired and added to the quarantine yard of sulfa-colonies. All responded rapidly to treatment with sulfa-sirup at the usual rate of one-half gram per gallon and have shown no symptoms of disease the past 6 months.

TREATMENT OF COLONIES WITH SULFATHIAZOLE IN HONEY-SYRUP.—Ten two-story colonies that were strong in bees but lightly infected with American foulbrood were obtained on August 21, 1947. The colonies had been a part of a 100 colony apiary that had been exposed to combs from 80 colonies later found infected with American foulbrood. Repeated inspections had indicated that only the 10 out of 100 colonies exposed had contracted the disease. The initial symptoms of infection in these colonies ranged from a single cell in each of five colonies to several cells in the others although additional cells of disease were found in each colony during the first week of treatment. The colonies were heavy with honey, so it was decided to extract the honey and feed it back to the infected colonies, after adding sodium sulfathiazole. From one colony, *S-35*, only 4 combs were extracted in order to give the colony more room in which to store the medicated honey-sirup and to rear brood. Some of the brood frames were left with sealed honey in their upper corners. Each 60 pounds of honey was diluted with 28 pounds of water in which 10 grams of sodium sulfathiazole had been dissolved. Each colony was given two 5-pound tins of honey-sirup at each feeding. Some colonies took the sirup faster than others but every colony received from 3 to 4 grams of sulfathiazole during the feeding period. All of the colonies were apparently free from disease by September 17 and were in excellent condition for winter at the time of the last inspection on October 31. They had been fed nothing but the honey that had been extracted from their combs, plus the sulfathiazole, but had gathered between 20 and 30 pounds additional of surplus honey. The

colonies will be held under observation for at least two years with their equipment kept separate from other colonies. Each colony will be divided in the spring in order to have brood reared in every comb as soon as possible. When additional supers are needed, frames of foundation will be given instead of drawn combs to reduce the possibilities of infection from this source. None of the colonies will be fed sulfathiazole again unless new evidence of American foulbrood is found, in which event each case will be treated as if newly infected.

THE DETECTION OF SULFATHIAZOLE WITHIN THE HIVE.—While much has been written about the use of sulfathiazole in the treatment of colonies infected with American foulbrood, little is known of the manner in which the drug affects the bees or how it is handled by them in effecting a cure. In an attempt to learn more about the disposition of the sulfathiazole after it is fed to a colony, analyses were made of the medicated sirup before and after it was fed and processed by the bees, together with samples of royal jelly, larvae and of bees taken from sulfathiazole-fed colonies. The results of these analyses are given in table 1.

Table 1.—Sulfathiazole determinations made with an Evelyn photoelectric colorimeter. Samples taken from colonies fed sulfathiazole in sugar-sirup.

SAMPLES	SULFATHIAZOLE, p.p.m.
1. Sugar sirup, 4.5 lbs. sugar, 4.5 lbs water, 0.5 g. Na. sulfathiazole	120
2. Same sirup, processed by bees, extracted from combs	146
3. Honey-sulfa-sirup extrated in 1946 #2	29
4. Honey-sulfa-sirup extracted in 1946 #6	83
5. Royal jelly from 2 day old queen cells, 6.26 grams	0
6. Royal jelly from 2 day old queen cells, 11.83 grams	0
7. Royal jelly from 3 day old queen cells, 16.08 grams	0
8. Royal jelly from 4 day old queen cells, 7.53 grams	15
9. Royal jelly from 4.5 day old queen cells, 7.28 grams	18
10. Worker larvae, 5 days old, 6.09 grams	36
11. Worker larvae, all ages	47
12. Queen larvae, 3 days old, 2.28 grams	32
13. Queen larvae, 4.5 days old, 10.45 grams	46
14. Bees heads, 5.28 grams	4 (trace)
15. Bees heads, colony not fed sulfa for 4 days	3.5 (trace)
16. Sample from 1200 lbs. of honey extracted in 1946 from sulfa-fed colonies	12

In sample 2 the sulfathiazole was present in the sirup processed by the bees in greater proportions than in the original sirup. This increase, of course, was due to the reduction in the moisture content from 50 per cent to approximately 18 per cent from the time the sirup was fed until it was extracted from the combs. (There was a dearth of nectar during the time the colonies were fed, precluding the addition of honey from natural sources.) The sulfa-sirup had been fed continuously over a three weeks period. The colonies were queen-right below queen excluders but produced queen cells in the chambers above the excluders. As indicated in the table, sulfathiazole was not found in the royal jelly taken from queen cells that were 2 and 3 days old but was present in considerable quantity in royal jelly taken from cells that were 4 and 4.5 days old. Sulfathiazole was also found in queen larvae 3 and 4.5 days old and in 5 day old worker larvae. Only a trace of sulfathiazole was found in the heads of bees taken from sulfa-fed colonies. In samples 3, 4, and 16 the sulfa-sirup was not extracted until after the bees had stored considerable honey in the same combs.

DISCUSSION.—It is quite commonly known that bees will store honey in cells containing American foulbrood scales when the colony is crowded for storage space. Such cells might well cause a recurrence of the disease if the colony uses up all of the sulfathiazole sirup fed in its treatment before the cells are emptied and cleaned out. Consequently, it would seem desirable in the treatment of a diseased colony to remove the combs of honey, extract them and to feed the honey back to the bees after diluting it and adding sulfathiazole. Since the sulfathiazole is retained in the honey or sirup fed, diseased colonies should not be fed any more sulfa-sirup than is needed to clear up the disease and no more than the treated colony can use in its own maintenance, before a surplus of honey is stored, in order to prevent the adulteration of extracted honey with sulfathiazole. While this possibility of adulteration is always present when-

ever sulfathiazole is fed, the probability of adding harmful amounts of sulfathiazole to honey is extremely slight, as indicated by Johnson & Stadel (1946), if the drug is fed only to colonies known to be infected. In case of honey-sirup extracted from the colonies fed sulfathiazole for the production of the samples given in table1, a person would have to eat from 2 to 20 gallons of the honey-sirup to get the equivalent of 1 gram of sulfathiazole. The amount of sulfathiazole in Samples 1 and 2 is several times greater than where the sulfa-sirup is diluted by honey from natural sources, as indicated by the 12 p.p.m. in sample number 16 taken from 1200 pounds of honey extracted from sulfa-fed colonies. These analyses indicate that the sulfa-sirup, fed either by entrance feeders or above the combs, is deposited in the supers as well as in the brood combs. For this reason, beekeepers should use extreme care to prevent honey from being adulterated with sulfathiazole even in minute quantities. When the prevalence of American foulbrood is as low as it is in California on a state average, it is doubtful if beekeepers can justify the feeding of sulfathiazole in sirup merely as a preventive to infection from this disease.

The danger of spreading American foulbrood to other colonies in the removal and extraction of honey from infected hives, the time and labor involved in treating a diseased colony as well as the need for holding such colonies in virtual quarantine for a year or more, will deter most commercial beekeepers from using sulfathiazole either as a preventive or as a cure for this disease. A vast majority of our California beekeepers, at least, prefer to destroy by burning the occasional colony found diseased, together with all of the infected combs, and to replace such colonies with new equipment, rather than to deal with the uncertainties of treating diseased colonies by chemical means. However, it is of scientific interest to find out the conditions under which sulfathiazole or any other chemical can be used safely and successfully in curing diseased colonies and in determining the manner in which such cures are effected. Until these facts are known the beekeeper should consider the use of sulfathiazole in the treatment of American foulbrood to be still in the experimental stage. It should be used only for the treatment of diseased colonies and these only under supervision of inspectors or research specialists.

The sulfathiazole fed to colonies in honey or in sirup is fed to the larvae by the nurse bees in time to prevent the development of the disease producing bacteria within the larvae. With the aid of sulfathiazole sirup, the bees can also clean out diseased cells without spreading the infection to other larvae. While bees apparently can do this to a limited extent naturally without the aid of sulfathiazole as indicated by Woodrow & States (1943) and Reinhardt (1947), the extent to which they removed diseased material from their combs never warrants leaving diseased colonies to their own resources to eliminate the disease.

SUMMARY.—Of the 19 colonies treated for American foulbrood in 1945 and 1946, all but two remained free from disease in 1947 and the source of the re-infection in these two could not be traced to the original combs. Eighteen additional colonies were successfully treated with sulfathiazole in 1947, 10 of them being fed back their own honey after it had been extracted, diluted and sulfathiazole added. Sulfathiazole was recovered from sugar sirup fed to bees after it had been processed by the bees and stored in their combs. Sulfathiazole was also demonstrated to be present in 4-day old royal jelly and in worker and queen larvae of colonies fed sulfathiazole in sugar sirup.

Due to the dangers of introducing even small quantities of sulfathiazole in marketable honey the general use of this drug as a preventive measure in the control of American foulbrood is not justified at the present time.

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Some Factors Affecting the Color of Honey

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The color and flavor of honeys as originally stored by bees seem to be rather closely associated. In general light colored honeys are usually mild in flavor and dark colored honeys strong in flavor. However, the treatment given to a particular kind of honey during extracting, processing, and storage may have a detrimental effect for whenever honey is darkened by any treatment there is also a spoilage of flavor toward the stronger side with a loss of or masking of the original aroma.

For every species of nectar-producing plant worked by honeybees there is a kind of honey distinct as to color and individual flavor and aroma due to variations in the chemical constituents of the original nectar. But there may be variations in honeys from the same plant source which are due to differences in the types of soil habitat and the rapidity of the honeyflow or volume of nectar secretion, with the possibility of contamination from other competing plants.

The chief constituents of honey which are known to contribute to the original color of honey are various plant pigments, including carotin, xanthophyll, anthocyanin, and some bright yellow and dark green pigments of unknown composition. Other original color contributing constituents are colloidal particles, tannin bodies as in buckwheat, and chlorophyll derivatives or decomposition products.

The apparent original color of honey, even though unaltered by subsequent handling by man is influenced by the color of the glass container, the quantity and quality of light behind it, and the mass or volume of honey through which the light passes.

Under normal conditions of marketing, comb section honey, if marketed early, usually reaches the consumer's table in a condition much the same in color, flavor, and aroma as when originally produced. But in extracted or liquid honey production other factors are commonly involved. Due to the fact that extracted honey has a greater tendency to granulate or crystallize, after which fermentation may cause spoilage and loss of flavor, it is common practice among honey producers and bottlers to heat honey to destroy the yeasts and to melt all incorporated dextrose crystals that might serve as nuclei or centers of crystallization. The tendency of a honey to granulate is primarily dependent upon the relative proportions of dextrose and levulose sugars. An unheated honey relatively high in dextrose, that is, one in which the dextrose content is near or greater than the levulose content, is subject to granulation when kept at a favorable temperature. On the other hand when the destrose content is low and the levulose content is relatively much higher there is less tendency to granulate or not to crystallize at all.

To prevent honeys likely to granluate from actually crystallizing the usual recommendation, after cold straining, is to heat the extracted honey to 155 to 160° F. in a water bath and hold at this temperature for approximately 30 minutes, then strain and place in the containers. With certain honeys showing a lesser tendency to granulate a lower temperature is often quite satisfactory. When all proper precautions are taken, the packaged product may be changed but little from the natural condition in which it was thrown from the combs in the extractor.

Serious discoloration and loss of flavor may result from the processing if direct heat rather than a water bath is used or even if the latter is applied for too long a time. Heating in a partially closed container is helpful in retaining the original aroma and flavor of honey which are due to the essential oils which may be driven off by the application of too much heat over too long a time. Providing some sort of mixing or stirring of the honey being heated is helpful in that the amount of time involved is greatly reduced. Once the honey is heated, it should be strained while hot, possibly partially cooled, then placed in the retail sales containers, and sealed immediately to prevent incorporation of unmelted dextrose crystals. Before being placed in the shipping cartons or cases, the individual containers of honey should be cooled to prevent excessive discoloration resulting from stack heat, which has been known to be maintained

Chicago program.

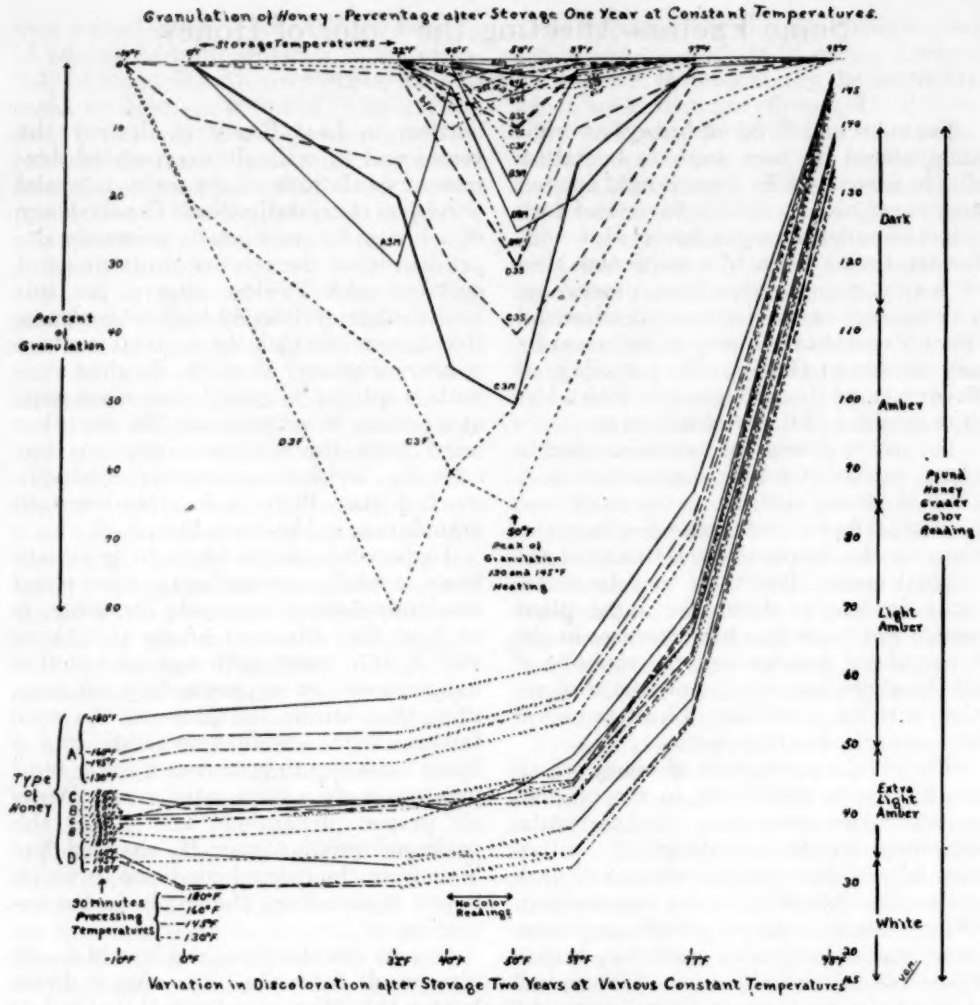

FIG. 1.—At top—Percentage of granulation of four different honeys after storage for one year at the constant temperatures indicated at the top. D—Capped summer honey, predominantly sweet clover; C—Uncapped summer honey; B—capped fall honey, largely heartease; A—Uncapped fall honey.

At bottom—The variation in discoloration of a part of the same samples of honey shown in the top graph, after storage for two years at the various constant temperatures −10° to 98° F. indicated at the bottom. All 30 minutes processing temperature 130°, 145°, 160°, 180° are shown but only the straining with sugar sack toweling included, there being practically no differences in discoloration due to the type of strainer used. Due to heavy granulation at 40° and 50°, color readings at these temperatures were omitted.

as long as 30 days with other food products packaged and piled in shipping cartons without first being cooled.

Still another form of discoloration of honey is that resulting from storage in metal containers. When galvanized containers are poorly tinned there may be some discoloration due to contact of the acids of the honey with the metal. Most serious is ungalvanized iron in the joints, cracks, and crevices of tanks and the fittings of pipe lines, honey pumps, and storage tanks. Some of this type of discoloration may be eliminated by the use of glass or porcelain-lined containers, or largely prevented by making sure that all iron is well galvanized and by thoroughly removing all honey after each use. A similar type of metal discoloration results around the lids of tin containers and those of jars where the inner seal does not prevent honey coming in contact with the metal lid. The latter may be prevented by tight fiting caps and by avoiding honey on the lips of the jars as they are being filled.

Wilson & Marvin (1931a) of the Wisconsin Experiment Station called attention to the deteriorating effects of storage of honey at high temperatures, when they reported that samples stored at 40 and 60° F. did not change in color while those at 80° became slightly darker and were inferior to taste to those stored at 60°. Their samples stored at 100° "changed from water white to almost amber and lost much of the delicate flavor of the honey." After another year of storage, they (Wilson & Marvin 1931b) reported that samples stored at 80° for 2 years showed a decided change in color and flavor.

Graphic evidence of the results of storage of honey at various temperatures was presented by Milum (1939) and is reproduced here (Fig. 1, 2, 3) for comparison with more recent results. In figure 1 is shown the discoloration of four different samples of honey processed at 130, 145, 160 and 180° F., and stored at various temperatures from −10° F. to as high as 98° for a period of 2 years. A study of this figure reveals that there was comparatively little discoloration at temperatures below 59°, but at 77° the discoloration was much more pronounced and quite severe at a storage temperature of 98°. Furthermore, a close scrutiny of the rates of discoloration of any given sample of honey with its variable original processing temperature will indicate that the total discoloration at any given storage temperature is in similar proportion to its color attained after the original heating, with the comparative total discoloration being reduced for the higher processing temperature as compared to its respective lower processing temperature. In other

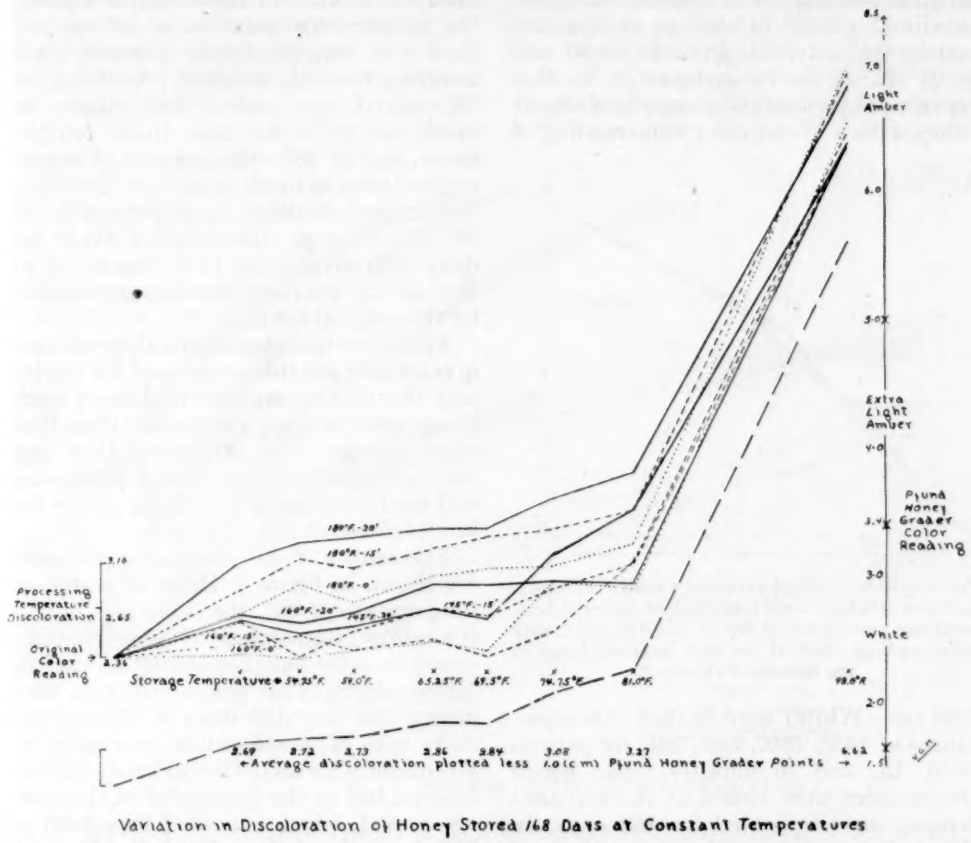
Light Amber
Extra Light Amber
White
Pfund Honey Grader Color Reading
Processing Temperature Discoloration
Original Color Reading
Storage Temperature
Average discoloration plotted less 1.0 (c m) Pfund Honey Grader Points
Variation in Discoloration of Honey Stored 168 Days at Constant Temperatures

FIG. 2.—Variation in discoloration of similar portions of a honey stored for 168 days at variable constant temperatures, with each line representing a particular processing temperature and time, as indicated by the figures above the line, i.e., that at the top being the color readings of the samples processed at 180° F. for 30 minutes before being stored.

words, the difference in color between two samples of a particular honey after processing at a low and at a high temperature was greater than the difference in color of these same two samples after storage for two years at a high temperature.

In an attempt to gain more exact information as to the critical point of storage temperature in relation to honey discoloration, another series of samples was processed and placed in storage at approximately 0.5° intervals from 55 to 80 and at 98° F. as shown in figure 2. In this experiment portions of a sample of clover honey with a Pfund color scale reading of

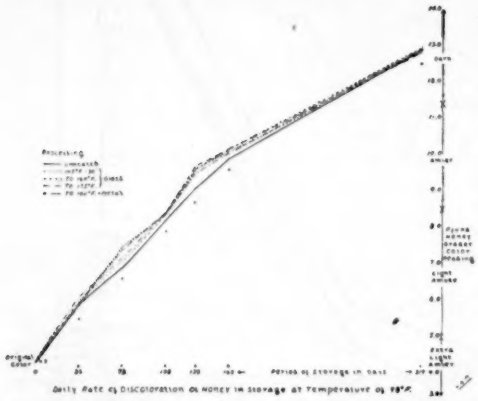

FIG. 3.—Rate of discoloration of a sample of honey, portions of which were processed at different temperatures and stored at 98° F. for 319 days, with color readings made at the time intervals listed at the bottom of the chart.

2.36 cm. (White) were heated at temperatures af 145°, 160°, and 180° for periods of 0, 15, and 30 minutes, after which the samples were stored at the constant temperatures indicated for 168 days. In the extreme original heating, that of 180° for 30 minutes, the original color was only increased to 3.10 cm., a total of 0.74 cm. or approximately 42 per cent of the expanse of the white grade.

Further examination of figure 2 will show that with storage at the variable constant temperatures, there was very little further color change during the 168 days of storage at temperatures below 70° F., but definite discoloration at a temperature of 75° more marked changes at 81° and quite pronounced or serious discoloration at 98°. Considering the average coloration of the eight sets of samples as shown by the isolated broken dash (– – – –) line at the bottom of the figure, we find that if the average original heating discoloration (.33 cm.) for all of the samples shown in the figure is considered as 100 per cent, then the additional average discoloration in storage for the 5° intervals during the 168 days is as follows in per cent: 55°—9.1, 59°—12.1, 65°—51.5, 69°—45.4, 75°—118.2, 81°—175.7, and 98°—1190.9 per cent. In more simple figures, the average discoloration at 70° in 168 days was approximately one-half that resulting from the original processing, at 75°—about one and a fifth times as much, at 81°—one and three fourths times, and at 98°—the extreme of nearly twelve times as much as that produced by the original heating. In other words, at 98° the average discoloration every 14 days (168 divided by 11.9) was equal to that of the average discoloration caused by the original heating.

Again, in this experiment, the variation in color between the extremes of the lighter and the darker samples or lots of each honey after heating are greater than that after storage, thus indicating that any excessive discoloration during processing will tend to decrease to a slight extent the rate of discoloration in storage.

The results of still another experiment are shown in figure 3. Here, at a storage temperature of 98°, the daily rate of discoloration of an unheated honey is compared to other samples heated at various temperatures. This graph indicates that during the first 133 days of storage the daily rate of discoloration was more or less uniform for all of the variously treated honeys, but in the remainder of the storage period, which extended to a total of 319 days, the daily rate of discoloration was decreased, with all of the samples attaining approximately the same degree of coloration. This again indicates, as previously intimated, that any discoloration by the original processing procedure tends to decrease the future rate of discoloration in storage particularly during the later part of the storage period.

As a possibility of further substantiating the apparent results in the previous experiments, graphically illustrated in figures 1, 2 and 3, another experiment was set up in January 1946. Three samples of honey were selected. The first, A, was honey produced during the summer of 1945, being largely a mixture of clovers.

The second, B, was produced during the 1945 fall period, apparently being largely of smartweed origin, mixed with other fall flowers. The original composite sample, C, consisted of 28 pounds of 1943 honey or that of previous years, and 7 pounds of the 1944 crop, the latter probably largely from soybean. All portions of sample C presumably had been heated and as a result were darkened from this and from the natural discoloration from storage, being purposely chosen because of a need for a honey previously darkened beyond its original condition.

empty space of approximately an inch at the top to prevent any possible color contamination by contact of the honey with the iron of the rim of the lid of the jar.

The individual samples were allowed to cool normally at room temperatures. Pfund color scale readings were taken during January 6, 7 and 8, after which the various samples were placed in storage where they were kept constantly during the experimental period except the occasional intervals of 1 to 2 days when they were removed to room temperature

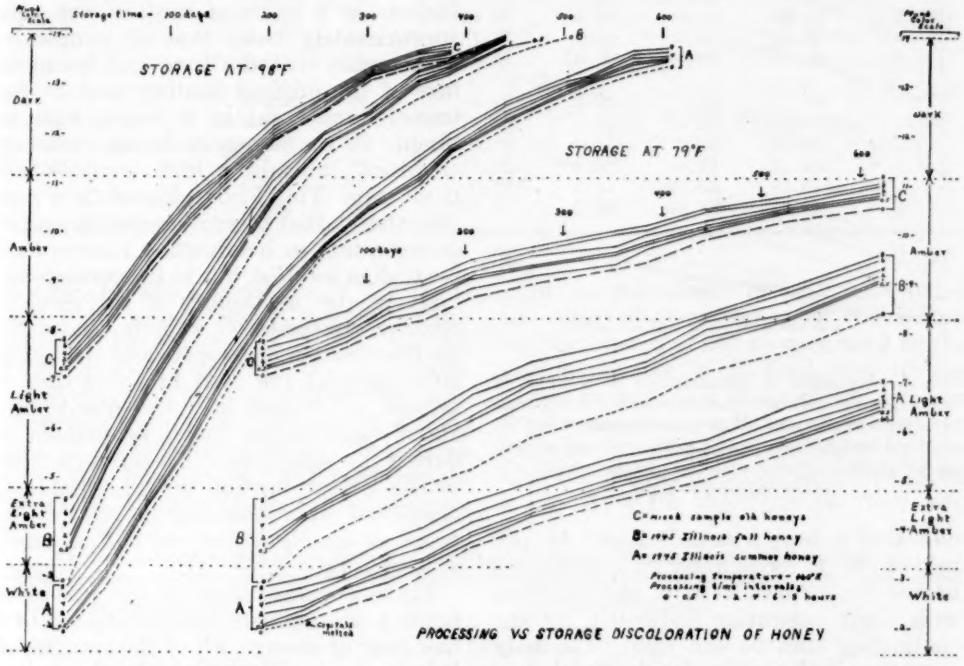

FIG. 4.—Variation in discoloration of samples of three different unheated honeys stored at 79° F. and 98° F., compared with similar samples heated to 160° F. and held for 0.5, 1, 2, 4, 6, and 8 hours.

On January 5, 1946, large samples of each of the three honeys, contained in bell jars, were placed in a circulating water bath and the heating process started at 8 A.M., the water being heated by steam escaping from a rubber hose. By 9:45 A.M. the temperature of the honey reached 160° F. and was maintained at approximately that point until 5:45 P.M. or a period of 8 hours after reaching 160°. Experimental samples of each of the three honeys (A, B, C) were removed, after thoroughly stirring the composite samples every half hour, the honey being placed in half pound jars, leaving in each an

for color determinations. While there may be some slight discrepancies in the color changes during the period required for color readings, it is apparent from a study of the curves shown in figure 4, that the amount of color variations resulting in the short period of not being in storage are insignificant as compared to the total discoloration while in storage at temperatures higher than room temperature. The constant temperature storages available were 79° and 98° F. shown in figure 4, while the results of discoloration at room temperatures are shown in figure 5, which indicates comparative color changes in

similar examples stored in darkness and exposed to light. Now if we examine figure 4, we note that the original color of the honey is indicated by the extreme left hand end of the broken-dash line at the bottom of each group of samples, in which for each honey are included the

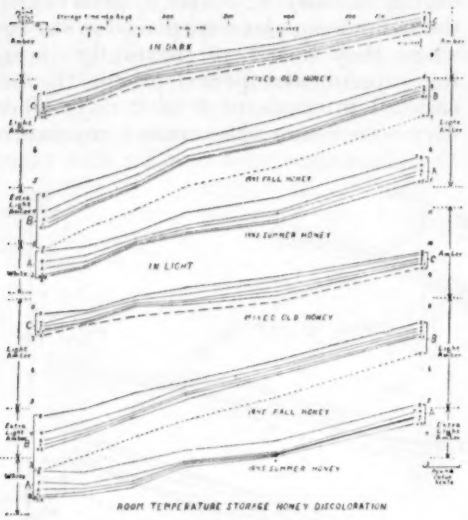

FIG. 5.—Variation in discoloration of samples of three different unheated honeys stored at room temperature and portions of the same heated to 160° F. and held for 0.5, 1, 2, 4, and 8 hours, with one of each pair of samples stored with light excluded and the other exposed to light.

unheated honey, a sample raised to and held at 160° F. for 30 minutes, and samples heated for 1 hour, 2, 4, 6, and 8 hours, with their coloration indicated by the continuing lines to the right. The only exception is the original unheated honey of sample A at 79°. It was found necessary to heat it to melt the crystals formed at the end of the first 40 days. Also it should be noted that for sample C, even though the lower dark line is indicated as an unheated sample, it actually had been heated 2 or 3 years before the start of the experiment and likewise was darkened during the intervening period of storage at room temperatures.

Examination of the curves of figure 4 and the tabulation of table 1 will show that the raising of the temperature of the honeys to 160° which required an hour and 45 minutes and the subsequent holding at that temperature for 30 minutes caused initial discolorations of 0.05, 0.67 and 0.13 cm. Pfund grader points for samples A, B, and C, respectively. For each of these three honeys, the additional discoloration by holding at a temperature of 160° F. for the total period of 8 hours (Table 2), gave a total discoloration of 0.86, 1.70 and 0.68 cm., respectively.

Examination of these respective discolorations indicates that sample A discolored 16.2 times as much during the 7.5 hour period beyond as during the original period of raising to 160° F. and holding for 30 minutes. While sample B discolored 13.4 times as much as sample A during this initial period, its total discoloration during the 8 hours of heating was only approximately twice that of sample A. This means that the time and temperature of the original heating may be extremely important in a honey such as sample B, the non-granulating tendency of which indicates a high levulose-dextrose ratio. This lends support to a possible theory that there is greater danger of deterioration in overheating honeys that are high in levulose, due to the correspondingly greater unstability of the levulose portion. For sample C, we note, that while its discoloration previous to and during the 30 minutes at 160° was 2.6 times that of sample A, it was still discolored only about one-fifth as much as sample B during the same period. In the remainder of the 8-hour heating period, sample C discolored approximately two-thirds as much as sample A and one-half as much as sample B.

Further examination of the curves of figure 4 will indicate that during the first half year of storage, all of the samples of B honey, regardless of whether heated or not, darkened at a greater rate than the samples of A, while the rate of C samples was less than those of A. Examination of table 4, which gives the increase in color by half-year periods for the unheated samples of the three honeys, indicates that the additional discoloration during the second half year (180 to 365 days) period was greater for sample B than for sample A at a storage temperature of 79° F. but at a lesser rate than sample A at 98° F. This slower rate at 98° in the second half year is, no doubt, due to the extremely heavy amount of previous discoloration of sample B. Likewise, apparently for the same reason, the rate of discoloration of the unheated

Table 1.—Comparison of storage discoloration at 98° F. and 79° F.

Sample (Unheated)	Storage		Discoloration in Storage				Ratio
	Days	Temp. °F.	Up to	Increase	Multiples of heating	Days to equal	98°/79°F.
A	0–180	79	3.44	1.49	29.8	6.00	
1.95 to 2.00 at	0–180	98	7.45	5.50	110	1.64	3.69
160° F. 30 min.	180–365	79	4.68	1.24	24.8	7.46	
(0.05)	180–365	98	11.14	3.69	73.8	2.51	2.98
	365–547	79	5.72	1.04	20.8	8.75	
	365–547	98	13.08	1.94	38 8	4.72	1.87
	0–605	79	6.15	4.20	84	7.20	
	0–605	98	13.40	11.45	229	2.64	2.73
B	0–180	79	5.24	2.35	3.51	51.25	
2.89 to 3.56 at	0–180	98	9.45	6.56	9.79	18.39	2.80
160° F. 30 min.	180–365	79	6.55	1.31	1.96	94.39	
(+0.67)	180–365	98	12.88	3.43	5.12	36.13	2.62
	0–437	79	7.13	4.24	6.33	69.04	
	0–437	98	13.59	10.70	15.97	27.36	2.52
C	0–180	79	8.45	1.33	10.23	17.60	
7.12 to 7.25 at	0–180	98	11.35	4.23	32.54	5.53	3.18
160° F. 30 min.	180–365	79	9.38	.93	7.15	25.87	
(+0.13)	180–365	98	13.47	2.12	16.31	11.34	2.28
	0–384	79	9.43	2.31	17.79	21.61	
	0–384	98	13.51	6.39	49.15	7.81	2.77

sample of C has a lesser rate of discoloration than both A and B samples in the first half-year period as well as the remainder of the year. From the appearance of the curves, it is apparent that the same conclusions could be drawn for the samples of each honey variously heated as have just been made for the respective unheated samples of the three honeys.

In the last column of table 1 are listed the ratios of discoloration of the heated samples stored at 98° as compared to the discoloration at 79° F. Each ratio for the period indicated is obtained by dividing the increase in coloration at 98° by the increase in color at 79°. Thus for the first 180 days, the ratios were 3.69, 2.80, and 3.18 for the three honeys, A, B, and

Table 2.—Comparison of coloration of unheated honeys with samples heated eight hours.

Before Storage		After Storage			
		Room Temperature			
Sample	Original Color	Light	Dark	79°F.	98°F.
		(All 618 days)			
				618 days	*605 days*
A8	2.81	4.90	5.75	7.01	13.77
AO	1.95	4.73	5.62	6.23	13.40
Dif.	+ .86	*+ .17	+ .13	+ .78	+ .37
				616 days	*437 days*
B8	4.59	7.48	8.30	9.58	14.01
BO	2.89	6.50	7.05	8.38	13.59
Dif.	+1.70	+ .98	+1.25	+1.20	+ .42
				619 days	*384 days*
C8	7.80	9.73	10.37	11.17	13.85
CO	7.12	9.22	9.77	10.55	13.51
Dif.	+ .68	+ .51	+ .60	+ .62	+ .34

* The low values shown for the differences between the unheated sample and that of A honey heated to 160° F. for eight hours is probably due to the heating necessary to reliquify the former after complete granulation in storage.

C, respectively. In the second half year period (180 to 365 days), these ratios were reduced to 2.98, 2.62 and 2.28, respectively. The ratio for sample A honey for the third half year period (365 to 547 days) was further reduced to 1.87, while all samples of B and C honeys stored at 98° had obtained a color beyond the limits of the Pfund colorimeter. These ratios again indicate that if a honey has already been darkened somewhat by the treatment given it, thereafter in storage the rate of discoloration will be reduced in comparison to a similar sample not already darkened.

While no one would recommend heating honey for longer than 30 minutes at a temperature of 160° F., the periods up to 8 hours were included in the experiment to see what effect this original discoloration might have upon the rate of discoloration in storage. Contrary to what some claim, this original excessive discoloration does not cause an increased rate of discoloration in storage. If one should examine the charts only casually, he might conclude that there is no effect, for the coloration curves for the various samples seem to follow each other more or less parallel throughout the period of storage, except for minor variations which cannot be avoided when a colorimeter such as the Pfund honey grader is used. However, a close examination of the six sets of curves in each of figures 4 and 5 for the three kinds on honey under two sets of storage conditions, will indicate that the difference between the original sample of honey and that of the same sample heated to 8 hours is greater at the beginning of the storage period than at the end of the storage period. As proof, note that the vertical width of the band for each particular group of samples (least discoloration or no heating to greatest discoloration or heating at 160° F. for 8 hours) is wider at the beginning than at the end of the storage period. The actual data in support of this statement is shown in table 2 which gives the coloration grade points for the samples of each of the unheated honeys previous to the storage period, that of the samples heated to 160° for 8 hours, and the colors of the respective samples after storage at the various temperatures. The figure for the difference in coloration between the two respective samples after storage is less in each case than the difference in color of the same respective samples at the beginning of the storage period.

Further proof of another result in honey storage, to which we (Milum 1939, 1946, 1945) have called attention previously, is given in figure 5. Here again samples of similar honeys stored in the dark or with light excluded actually have a greater rate of apparent discoloration than the corresponding samples exposed to light. The word "apparent" is used here because it is felt although no proof is submitted that the rate of actual discoloration is probably the same for the two samples, since it is doubtless a chemical reaction, but that in the case of the samples stored with exposure to light, there is a bleaching effect upon the products formed that contribute to color.

Because our original conclusion (Milum 1939) on storage in light versus storage in the dark was contrary to the statements of others who had not conducted controlled experiments, a larger number of samples were included in this experiment. Portions of the same three samples of honey (A, B, C) as used in the storage at 98° and 79° illustrated in figure 4, were utilized, with the exception of the samples heated to 160° for 6 hours. They were stored in an ordinary room with light or window exposure to the north only. Additional light came at times from the electric lights in the classroom. One jar of each pair of samples was placed inside a cardboard carton which excluded all light, while the other jar was stored immediately outside the carton adjacent to its mate but exposed to the light. The thermostat control in the room held the temperature at about 72° during the greater part of the year when heat was available, but during the summer months the temperature of the room seldom if ever exceeded 85°.

Examination of the data and the color curves, as shown in figure 5, shows that in every one of the 18 corresponding pairs of samples, the honey stored in the dark was darker at the close of the 618 days period of storage than the honey stored in the light. This difference varied from 0.54 to 0.64 cm. color grade points for the six pairs of samples of C honey, from 0.55 to 0.72 cm. for B, and from 0.78 to 0.89 cm. for five pairs of samples of A honey. The two samples of A honey heated to 160° F. for 30 minutes, showed

a difference of only 0.46 cm. points, no doubt, due to an erroneous exchange in place of storage of the two samples during the period from Sept. 15 to January 26, which would tend to equalize their colors. It should be noted that in the case of the unheated samples of A honey, for which no discoloration curve is included in figure 5, that it was necessary eventually to reliquify these samples for they both granulated solidly soon after the start of the storage period. Both samples were subjected to the same amount of heating to melt the crystals, the discoloration resulting probably being greater than that by the original heating of the sample raised to 160° and held for 30 minutes. The readings after they had been granulated for over a year, showed that the discoloration took place in the granulated sample at about the same rate as in the corresponding heated samples that did not granulate, and with the one in the dark at a rate correspondingly darker than the one stored in the light.

There is not much practical value that can be applied to this last bit of evidence, since it is obviously impossible to store large quantities of honey under the bleaching effects of light. Furthermore, it is doubtful if the bleaching would have any improving effect upon the stronger flavor imparted to the honey by the darkening which might occur at any storage temperature. The information does refute the erroneous statement that honey stored in the light such as a store window tends to get darker because of the light. Actually the darkening is a result of the increased temperature to which the honey is subjected because of the sunlight.

To round out the subject of this paper it seems advisable to give a brief résumé of the literature dealing with the actual chemical factors involved when honey is darkened by processing and by storage at high temperatures. For more complete information than the summarization to be given in the remainder of this paper, those who are interested should consult the author's discussions in previous papers (Milum 1939a, b; 1946, 1945) as well as those of Phillips (1930, 1940).

Ramsey, in 1923, attributed the discoloration in poorly tinned honey containers to the contact of the acids of honey with the metal resulting in the formation of iron tannates.

Phillips (1930) stressed the danger of overheating honeys, pointing out that the changes occurring are a result of a breaking down of some of the levulose and the consequent formation of caramel, which darkens honeys and ruins their flavor. He warned against application of excessive heat over too long a time and recommended quick cooling to reduce danger of scorching.

Lothrop & Paine (1931 a, b) suggested that honey colloids (nitrogenous substances or proteins, highly emulsified wax particles, pentosans and inorganic substances) are responsible for the low caramelization point of honey because of their ready decomposition at elevated temperatures. They indicated that after the removal of the colloids by ultrafiltration from buckwheat honey, cooking qualities equal to the best light honeys were obtained. However, Lothrop & Paine (1939a) in 1933 and Paine *et al.* (1934) suggested that additional substances amino acids, probably play an important part in the caramelization of honey because honeys after the removal of colloids still showed a greater tendency to caramelize at high temperatures than corresponding sugar solutions. They further suggested that since the albumens and other proteins of honey are the probable source of amino acids, the removal of the colloidal substances would inhibit the formation of amino-acids that might be produced by protein digesting enzymes. They attributed the actual darkening of honey when heated or when stored to the formation of dark-colored substances (melanoidins) by the reactions of amino acids and related compounds with dextrose and levulose.

Ramsey & Milum (1933) submitted some slightly conflicting evidence, when they suggested that Ramsey (1932) had demonstrated that with some food products, the discoloration and development of "caramel" flavor are due to a reaction between sugars and proteins, the aldehyde or ketone radical of the sugar condensing with the amino acids liberated during heating, this reaction resulting in the formation of substances which resemble caramel in color and flavor. Ramsey & Milum (1933) stated that when formaldehyde, a poisonous substance which has the property of tying up the amino acids of honey and preventing their reactions

with the sugars, was added to 10 samples of various honeys, there was no color change during heating at 250° for 15 minutes. They attributed the cause of honey discoloration in heating to the free amino acids, because their tests indicated that the removal of the colloids had little effect upon the discoloration during heating.

A 1935 report (Lynn *et al.* 1936) indicated that after a year there was no significant difference in the total nitrogen content of samples representing extremes of heat treatment and storage. They suggested that darkening is due primarily to the instability of frúctose and that the matter of nitrogen compounds is of secondary importance. A somewhat similar conclusion was made by Willaman & Easter (1929) when they concluded that fructose (levulose) is the most important source of color when sorghum juice is heated.

DeBoer (1934) reported that acidity does not change with age of honey. Becker (1936), reporting upon observations of honey samples after 133 days of storage (Fig. 3) stated that the amino nitrogen content decreased with an increase in storage temperature and in length of storage, which he attributed to the fact that at higher temperatures, the amino acid-aldol condensation reaction took place more rapidly than the hydrolysis of proteins to free amino acids. Becker also stated that the pH (acidity) remained unchanged within experimental error. The writer is indebted to Dr. Duane T. Englis of the Chemistry Department of the University of Illinois who in an unpublished report indicates after chemical analyses that in the samples shown in figures 4 and 5 of this paper, the differences in pH are so slight as to be negligible when comparison is made of samples of the extremes of no heating and heating to 160° for 8 hours and storage at room temperature and 98° for nearly a year.

Lynn *et al.* (1936) concluded that the three principal causes of honey discoloration are: (a) an amino acid-aldol combination; (b) the combination of tannates and other polyphenolic substances with iron salts; and (c) the unstability of fructose which is probably of primary importance. Milum (1939) reported upon the comparative discoloration of similar samples, unfiltered and filtered by Becker (1936) in which he used the methods outlined by Lothrop & Paine (1939). No significant differences in color between comparable filtered and unfiltered samples were obtained after storage for 1010 days. Similar results have been obtained by the writer when commercially filtered samples were observed in comparison with strained samples of the same honey.

While there may be some differences in opinion as to exactly what chemical changes are involved when honey darkens during heating and storage, it is certainly evident that this discoloration varies with different honeys and is directly related to the time and temperature of the processing period and of the subsequent storage period, the latter being highly important when high temperatures are involved. Since deterioration of flavor and aroma are also involved, proper care in processing and storage should be exercised.

SUMMARY.—Although previous investigations show that from temperatures of 70° F. upward there is a rapid increase in the rate of discoloration of honey in storage, the evidence presented in this paper shows that discoloration at a temperature of 98° may be as high as 3.69 times that of a similar honey stored at 79°, the rates decreasing with the extended length of the storage period. While a sample of unheated clover honey was darkened only 0.05 cm. grade points by heating to 160° for 30 minutes, a similar degree of discoloration resulted when an unheated sample was stored at 98° for 1.64 days or as much as 110 times during a half year of such storage. Even at 79° the corresponding figure is 6 days, with nearly 30 times the heating discoloration in 6 months of storage time. This emphasizes the importance of keeping extracted honey at low temperatures, preferably below 70°.

The evidence indicates that the amount of discoloration of a honey during any given period of heating or storage is in part dependent upon the amount of previous discoloration. Any discoloration occurring during the processing of honey for marketing or during storage because of high temperatures tends to lessen rather than increase the rate of discoloration in subsequent periods.

While some indication is given of the possibility that the danger of overheating an original honey or its deterioration in

storage may be closely associated with its levulose-dextrose ratio further tests should be made with a large group of unheated freshly produced samples of honey having variable levulose-dextrose ratios.

Further evidence is submitted in proof of a previous claim that honey stored in the light does not darken as fast as a similar lot stored at the same temperature but with the light excluded. Since honey discoloration is thought to be due primarily to the unstability of the levulose portion of honey with the formation of compounds which give a dark color, light apparently has a bleaching effect upon these compounds.—1-20-48.

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JOHN V. OSMUN JOINS PURDUE ENTOMOLOGICAL STAFF

John V. Osmun has been appointed assistant professor of Entomology at Purdue University to take charge of the new courses in the new 4-year curriculum for pest control operators. Professor Osmun graduated from the University of Massachusetts and obtained his Masters degree from Amherst. For three years of his four years in the Army he was entomologist of the First Service Command and later was connected with the research department of Merck & Company.

SCIENTIFIC NOTES

DDT as a Summer Spray Against European Elm Scale

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Various strengths of DDT both as a wettable powder and an emulsifiable oil were tested as a summer spray against the European elm scale, *Gossyparia spuria* Mod., on American elms in an abandoned nursery block near Bridgeport, Indiana. The trees, about 15 feet tall, were sprayed July 19, 1946, when nearly all of the crawlers had settled on the leaves. The spray was applied at 175 pounds pressure and approximately 0.9 gallon was used per tree.

The weather was very dry during the summer of 1946, no rain falling from July 4 to September 3 except for a one-half inch showed on August 5. The maximum temperature on July 19, the day the sprays were applied, was 97° F.

Two formulations of DDT were used: a 50 per cent wettable powder[1] and a 25 per cent emulsifiable oil[1]. The wettable powder was applied at strengths of 0.5 1, 2, 3, and 4 per cent of actual DDT, and the emulsifiable oil at strengths of 0.5 and 2 per cent of actual DDT.

Table 1.—Results of tests with DDT as a summer spray on European elm scale, 10 and 19 days after application.

Concentration of DDT in Spray	July 29		August 7	
	No. Scales	Per Cent Dead	No. Scales	Per Cent Dead
Wettable powder				
0.5	566	78.2	488	97.7
1.0	533	95.5	724	97.8
2.0	346	93.8	510	98.2
3.0	355	97.2	439	98.6
4.0	291	98.2	536	98.9
Emulsifiable oil				
0.5	1236	91.4	1250	99.4
2.0	613	94.8	682	99.1
Check	1070	7.0	718	8.6

Single tree plots were used, each treatment being replicated 5 times. The infestation of the old female scales on the trunks of the trees was rated at the time of the spray application as light, medium, and heavy. Counts of the young scales on the leaves were also made at time of treatment, the scales on 10 leaves taken at random from each tree being counted. The insects on a random sample of 10 leaves from each tree were examined on July 29 and again on August 7, 1946. On July 14, 1947, approximately one year after treatment, the trunks and a 10-leaf sample from each tree were examined for the presence of scales on both the check and treated trees.

As shown in table 1 all of the treatments, except the 0.5 per cent DDT as a wettable powder, had killed over 90 per cent of the scales by July 29, 10 days after application, and that by August 7 all of the treatments had killed over 97 per cent of the scales. When the trees were examined, on July 14, 1947, approximately a year after the treatments were applied, old female scales were found on the trunks of all five of the check trees and young scales were abundant on their leaves. No scales were found either on the trunks or on the leaves of any of the treated trees.

The 2 per cent DDT as a wettable powder caused slight and the 3 and 4 per cent strengths moderate burning of the leaves. The 2 per cent DDT in the emulsifiable oil caused severe burning of the leaves and about 50 per cent of them to drop, within 20 days after application. The 0.5 and 1 per cent wettable powder and the 0.5 per cent emulsifiable oil caused no observable injury. In fact the foliage on these trees was in much better condition in September than it was on the untreated ones. When the trees were examined in July of 1947 no effects of any injury could be detected.

From the results obtained in the experiment, it would seem that one application of a spray containing 0.5 per cent of actual DDT applied in July will control the European elm scale.

[1] *Deenate 50-W* and *Deenate 25-R.*

A Carbon Tetrachloride Killing Bottle[1]

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An insect killing bottle which utilizes carbon tetrachloride as the toxic agent has been in use at the University of Arkansas for approximately the past year. The bottle is completely safe in the hands of young or inexperienced persons, and because of its simplified construction it requires much less time to prepare, maintain and clean than does the cyanide bottle.

The experienced entomologist may not insist on extreme safety in a killing bottle, and may use so few bottles that convenience in their preparation is not a major factor. However, where killing bottles are supplied to large classes of students, both safety and convenience become important.

This killing bottle is prepared by placing in the bottom of the desired bottle or vial a rubber stopper of a diameter appreciably smaller than the bottle. Sufficient carbon tetrachloride is poured over the stopper to submerge it. The bottle is then closed and allowed to stand until the carbon tetrachloride is absorbed by the rubber. In taking up the carbon tetrachloride the rubber stopper swells until it makes a tight fit with the sides of the bottle.This eliminates use of plaster of paris or cardboard discs to form a smooth surface over the killing agent. Ordinarily it is desirable either to use a very short stopper or to reduce the length of an ordinary stopper by cutting it in two with a razor blade. Otherwise it will occupy too much of the bottle, since swelling increases the length as well as the diameter.

As the bottle is used and the carbon tetrachloride

[1] Research paper No. 857, Journal Series, University of Arkansas, published with the permission of the Director of the Arkansas Agricultural Experiment Station.

volatilizes, the stopper shrinks away from the bottle and becomes loose. A small amount of carbon tetrachloride is then added to recharge the bottle and swell the stopper again.

If it is desired to remove the stopper when the bottle is being cleaned, it is necessary only to allow the bottle to stand open overnight, after which the stopper will have shrunk sufficiently to allow it to be shaken from the bottle.

The life of such a bottle is quite satisfactory; a month or two of moderate service is not unusual. Even shorter service would not be objectionable since recharging is simple. Its killing power on a wide variety of insect species has been found quite ample. An additional advantage is the fact that insects die in a relaxed condition, which simplifies setting of wings, legs and antennae.

Carbon tetrachloride, pure or in the form of cleaning fluid, can be bought at almost any drug or department store. County agents, vocational agriculture teachers and primary school students can therefore maintain such a bottle easily and perhaps be encouraged to collect and study insects more extensively.

Effect of DDT on Several Apple Pests and Their Natural Enemies

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Although recent outbreaks of several insect and mite pests following the use of DDT are generally attributed to the destruction of their natural enemies by this new material, little definite evidence has yet been presented to verify this supposition. The reduction of natural-enemy populations by DDT is not sufficient proof that it alone is responsible. Other factors may be involved, particularly with regard to the orchard mite problem, and the solution can be obtained only through careful field studies of populations under controlled experimental conditions. Such studies are now under way in Virginia on the orchard mites *Paratetryanychus pilosis* (C. & F.) and *Tetranychus* spp., the red-banded leaf roller, *Argyrotaenia velutinana* (Wlkr.), and the Comstock mealybug, *Pseudococcus comstocki* (Kuw.). Certain preliminary results obtained during 1947 may be of interest to other workers on these and similar problems.

ORCHARD MITES.—For the mite experiments study blocks were arranged in six central Virginia apple orchards which received various codling moth spray schedules of lead arsenate or DDT or both, all of which were applied by growers. Direct comparisons were thus possible within or between orchards having straight lead arsenate or DDT schedules, or combination treatments of both materials.

The population data were based on bi-weekly brushing counts of the mites and eggs on 200 leaves in each block; 20 leaves were collected from each of the same 10 trees at each visit. Since very few of the larger and more active predators were recorded by this method, visual examinations for 1 hour were also made on each sampling date. Quantitative information on total predator and mite populations was thus available for study.

Early in the summer mites were consistently more numerous in the lead arsenate blocks than in those treated with DDT. This situation continued through July and most of August, but in September the DDT blocks forged slightly ahead. The expected severe mite outbreaks following the use of DDT failed to materialize, even where the heavier schedules were applied. In fact, from June through August there were about twice as many eggs and mites in several of the lead arsenate blocks as on adjacent trees of the same varieties which had received up to four or five applications of DDT.

Although sustained high populations occurred in each of the study orchards throughout the summer, with maximum counts of from 48 to 197 eggs and mites per leaf, there was no severe bronzing and little apparent injury to the foliage—perhaps owing to unusually favorable growing conditions.

The European red mites comprised 88 per cent of the total number of eggs and mites. Most of the remaining 12 per cent were two-spotted spider mites, *Tetranychus bimaculatus* Harvey. The other mites resembled *T. schoenei* McGregor, which is known to occur in this area. *Tetranychus* spp. were present in each of the six study orchards, but they outnumbered the European red mite only in one which had received a heavy DDT schedule. Dean (1945, 1947) and Dewey (1947) in New York State have found that DDT promotes outbreaks of the two-spotted spider mite but not the European red mite.

Mite predators were very scarce until August and September, when a general increase occurred in most of the orchards. With one exception this increase came too late to have any appreciable effect except on the overwintering mite populations. In one orchard treated with lead arsenate the infestation dropped from 44 to only 5 mites per leaf immediately after a rapid influx of predators early in August. There was a similar reduction just two weeks later in a neighboring block which had received 5 applications of DDT between May 6 and June 17.

Stethorus punctum (Lec.), though rather unpredictable, was the most abundant and important mite predator, comprising 80 per cent of the total predator population. This coccinellid was easily killed by DDT. A predaceous mite, *Iphidulus* sp., and the thrips *Leptothrips mali* (Fitch) and *Scolothrips sexmaculatus* (Perg.) were very scarce except late in the summer or in blocks where no DDT was used. Other species of less importance were various Chrysopidae, Coccinellidae, Syrphidae, and the Hemiptera *Hyaloides harti* Knight, *H. vitripennis* var. *discoidalis* Reut., and *Orius insidiosus* (Say).

For the most part, the predators were very irregular in distribution and abundance even under apparently favorable conditions. The use of DDT also resulted in their suppression for 5 or 6 weeks after the final spray, and in some cases may have prevented successful biological control. The general ineffectiveness of mite predators in the study orchards in 1947 therefore sseemed to be due as much to their initial scarcity and irregular distribution as to the use of DDT.

Red-banded leaf roller: The experiments with the red-banded leaf roller were conducted in 10 orchards, 4 in central Virginia and 6 in northern Virginia, and were similarly organized with respect to DDT and lead arsenate treatments. First brood egg counts were made during April to determine initial population levels. Subsequent populations were determined by collecting larvae of the first, second, and third broods on a man-hour and per-tree basis during June, August, and October. These larvae were reared in the laboratory on apple foliage and fruit to obtain data on parasitization. Fruit-injury counts at harvest were also made in these orchards.

First brood populations were comparatively low

in most orchards where lead arsenate was used alone or in combination with DDT, but a general increase occurred in the second and third broods, especially where the heavier DDT schedules had been applied. It was quite evident that both DDT and lead arsenate had killed most of the young larvae, but survival was generally somewhat higher in the DDT than in the lead blocks. Most of the survivors were on watersprouts and suckers inside the trees where spray coverage was incomplete.

On the basis of one season's results, it appeared that the lower populations in the lead arsenate blocks were due largely to the superiority of this material as a larvicide. There was no clear-cut indication that the differences were due to the destruction of leaf roller parasites by DDT, since parasitization was nearly as high in the DDT blocks as where lead arsenate was used. The infestations varied widely, even under comparable conditions, possibly as a result of shifting host and parasite populations during the two-month periods between larval collections.

About 23 species of parasites were reared from first and second brood leaf roller larvae and pupae, of which 3 are known secondaries. *Triclistus fulvipes* (Cr.) was the most common parasite, and *Microgaster epagoges* Gah., *Goniozus platynotae* Ashm., and *Phytodietus vulgaris* Cr. were next in general abundance. *Chrysopa* larvae were apparently sometimes important as predators.

Comstock Mealybug: Studies on the Comstock mealybug in apple orchards in eastern United States have shown that DDT is extremely toxic to the parasites that normally hold this mealybug in check (Hough *et al.* 1945). This finding suggested the possibility of a general increase in mealybug infestation following the use of DDT for codling moth control. Although the parasites have in fact been practically eliminated in orchards receiving DDT spray schedules, the same treatments have also prevented mealybug increase. This is apparently a situation where host outbreaks have not followed the destruction of efficient natural enemies by DDT. Where no DDT has been used, the parasites are still present and effective, and mealybug infestations remain at low levels.

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Mosquito Spraying with DDT and the Two-Spotted Mite

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On July 14, 1947 an attempt was made to control mosquitoes by spraying wettable DDT powder by means of a power sprayer. In this operation the spray was directed to the vegetation surrounding a small pond and bordering an automobile parking space in a wooded area at North Stamford, Connecticut. The dosage used was one pound of actual DDT to 100 gallons of water. There was an abundant infestation of *Aëdes canadensis* Theobald and *A. vexans* Meigen present in the area both before and after spraying. In fact the results so far as mosquitoes were concerned were very unsatisfactory with a relief of only a few hours to the workmen in the area immediately after the application. This is readily understandable because DDT has no effect on the eggs, larvae or pupae of these mosquitoes and infiltration of adults from the surrounding areas takes place quickly.

The men working in the area had to fall back on repellents to allay the mosquito annoyance aud of these a new material developed by the army during the war (a combination containing dimethyl phthalate) proved entirely satisfactory, repelling not only mosquitoes but Simuliids, *Chrysops* and other pestiferous diptera as well. This material, however, affects plastics. One of the workmen found the plastic crystal on his wristwatch so badly clouded that he could not read the time.

Effects of the DDT spray, however, persisted in other ways, most of which were extremely undesirable. On the portion of the hedge of *Hydrangea arborescens* bordering the drive which was sprayed with DDT, a heavy infestation of the two spotted mite, *Tetranychus bimaculatus* Harvey, developed within a week after the application of DDT was made. On July 21, 1947, this hedge was sprayed with 0.25 per cent hexaethyl tetraphosphate in an effort to control the mites. No appreciable reduction of the mites and no spray injury resulted but by the end of August the DDT-sprayed portion of the hedge was practically defoliated. It was interesting to note at this time also the spray line which was distinctly discernible all around the parking space producing a marked contrast between DDT-sprayed and unsprayed vegetation. The foliage of the shrubbery and lower branches of trees which were hit by the DDT spray was then mostly yellow. This yellowing of the foliage was apparently due not to chemical burning by the DDT or accompanying ingredients but to a heavy infestation of the oak red mite, *Paratetranychus bicolor* Banks, on the oaks and maples and a fungus leaf spot on the azaleas.

On March 9, 1948, measurements of the terminal buds of the DDT-sprayed hydrangeas in contrast to the hydrangeas not sprayed by DDT were made. Fifty per cent of the DDT-sprayed terminal buds were found to be dead at this time while those living had an average length of only 3.6 mm. As a check, measurements were made of terminal buds on hydrangeas in the same hedge but in a portion where no DDT had been used. None of the terminal buds were dead here and the average length of the buds was 5.75 mm.—an average length more than 2 mm. greater than on the DDT-sprayed portion. The dying and lack of growth on the DDT-sprayed shrubs was due first to direct injuries caused by the two-spotted mite during the late summer of 1947 and second, to winter-killing of the hydrangea terminals and buds following systemic weakening as a result of the mite infestation.

Insecticides for Control of Spittlebug Nymphs in Wisconsin[1]

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and
J. T. MEDLER and E. J. O'NEAL,
Wisconsin Agricultural Experiment Station

Preliminary experiments with insecticides for control of the meadow spittlebug, *Philaenus leucophthalmus* (L.), and its varieties in alfalfa were conducted in 1946 by Scholl & Medler (1947). Further experiments on spittlebugs attacking strawberries, sweetclover, and alfalfa were conducted in Wisconsin by the writers in 1947.

Hatching of spittlebugs was 3 to 4 weeks later in 1947 than in 1946 because of continued cold, rainy weather in the spring. Infestation in 1947 increased over 1946 in the southern and central parts of the state and a heavy infestation persisted in the east-central part. In some of the plantings in Door County, all the stems in alfalfa and sweetclover and all the fruit clusters in strawberries were infested. Control of spittlebugs is needed in all three of these crops, but especially in strawberries, where yields and quality of the fruit are being reduced and difficulties in picking and marketing are increasing.

EXPERIMENTS ON STRAWBERRIES AND SWEETCLOVER.—The tests on strawberries and sweetclover were performed in Door County. On June 9, a 5 per cent chlordan dust was applied to two plots of approximately 0.125 acre at the rate of 25 to 30 pounds per acre with a hand duster. On June 16, 100 fruit clusters were examined in each of the treated plots and in two untreated plots. Almost complete control of spittlebugs was obtained in the treated plots. There was no reduction of spittlebugs in the untreated plots.

On June 12, a 5-per cent DDT dust and two chlordan dusts, 5 per cent and 2 per cent, were applied with power equipment to unreplicated 2-acre plots of sweetclover at the rate of 20 pounds per acre. Chlordan was much more effective than DDT (Table 1).

[1] Supported in part by the Research Committee of the Graduate School of the University of Wisconsin and funds supplied by the Wisconsin Alumni Research Foundation.

Table 1.—Per cent of infested stems[1] found in sweetclover at different intervals after treatment with DDT and chlordan dusts on June 12, Door County, Wis. Dosage, 20 pounds of dust per acre.

TREATMENT	JUNE 15	JUNE 19	JULY 1[2]
DDT—5%	93	86	79
Chlordan:			
5%	8	15	6
2%	26	38	57
Check (untreated)	99	99	95

[1] Count of 100 stems collected at random from each plot.
[2] Adult spittlebugs began to emerge on this date.

EXPERIMENTS ON ALFALFA.—In alfalfa fields both sprays and dusts were tested. In Fond du Lac and Dane Counties sprays were applied with 3-gallon pressure-type sprayers, at the rate of about 200 gallons per acre, on plots that averaged about 25 feet square. In Door County both sprays and dusts were applied with power equipment to duplicate series of plots of approximately 0.25 acre. The results of these tests are shown in tables 2 and 3.

Of all the materials tested, chlordan was the most effective. In Door County control was greater when the insecticides were applied early in the season. Data from plots dusted twice also showed continued reduction of infestation for several weeks.

The fact that the chlordan emulsion concentrate (Table 3) was material held over from 1946 may account for its apparent ineffectiveness.

Actually many more individual spittlebugs are killed by an insecticide than counts of spittle masses indicate. A reduction in the number of spittlebugs

Table 3.—Per cent of infested stems found[1] on 0.25-acre plots of alfalfa after treatment with chlordan and hexaethyl tetraphosphate. Door County, Wis.

TREATMENT	DOSAGE PER ACRE	DATE TREATED	DATE OF STEM COUNTS				
			June 11	June 16[2]	June 18	June 19	June 27
		June					
Chlordan dust:							
5%	20 lb.	6 and 16	20	21	—	6	5
		16	—	—	62	71	60
2%	20 lb.	6 and 16	45	86	—	65	73
		16	—	—	88	89	93
Chlordan emulsion, concentrate spray (1 lb. technical chlordan per 100 gal.)	100 gal.	6	100	87	—	96	93
Hexaethyl tetraphosphate spray (1 pt. per 100 gal.)	100 gal.	6	75	98	—	99	95
Check (untreated)	—	—	95	96	98	100	99

[1] Count of 100 stems selected at random in each plot.
[2] Count made before second dust application.

Table 2.—Per cent of infested stems[1] found in alfalfa after treatment with various insecticides. Dosage, approximately 200 gallons per acre.

Treatment	Fond du Lac County (Applied on June 9)		Dane County (Applied on June 19)
	June 12	June 26	June 21
Benzene hexachloride, 5% gamma (1 lb. per 100 gal.)	20	55	10
DDT (1 lb. per 100 gal.)	40	42.5	10
Chlordan (1 lb. per 100 gal.)	20	22.5	0
Hexaethyl tetraphosphate (1 pt. per 100 gal.)	90	80	—
Tetratethyl pyrophosphate (4/5 pt. per 100 gal.)	60	67.5	—
Check (untreated)	100	88	20

[1] Count of 40 stems collected at random from each plot in Fond du Lac County and 80 stems in Dane County.

per mass is correlated with a reduction in the number of masses per plot. Counts made in Fond du Lac County on June 26 indicated that less than one-fourth as many spittlebugs per mass were present following moderately effective treatments than in untreated plots.

Chlordan controlled spittlebug nymphs on strawberries, sweetclover, and alfalfa more effectively than either DDT or benzene hexachloride, both of which gave some control, and than either of the phosphates, both of which gave little or no control. To be very effective chlordan apparently should be applied when most of the nymphs are in the first or second instar. When it is applied to alfalfa or sweetclover at this time it seems to have both an immediate and residual action on the young nymphs migrating from the lower parts of the stems to the tops, where most of the late instars are found. The insecticide may also penetrate the small newly established spittle masses protecting the small nymphs more readily than the larger masses produced by the later instars. A 5 per cent chlordan dust seems to be strong enough to give a complete kill of spittlebugs within masses on strawberries, where the coverage is usually more uniform than it is on sweetclover and alfalfa.

Although chlordan is effective in reducing infestations of spittlebug nymphs, it cannot be recommended for use on food crops until more is known about its residual toxicity to human beings and livestock.

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Overwintering Habits of *Phaenicia sericata* (Mg.)

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During 1947 larvae of the species of fly mentioned were being reared in carcasses in an unheated greenhouse at New Brunswick, New Jersey for use in evaluating insecticides. In the first week of November it was observed that many full-grown larvae of a brood then feeding failed to form puparia, became light pink in color, and were inactive in the soil. They could not be induced to pupate when brought indoors, and did not feed when given food.

Examination of the sand and earth floor of the greenhouse on March 12, 1948 disclosed in the upper one inch many larvae of varied size. When brought indoors they formed puparia and emerged in about one week. Of 263 larvae collected, 242 pupated and 240 emerged.

This fly was also being reared in carcasses placed out-of-doors on the soil during the first two weeks of November. Examination of the soil nearby showed the presence of many larvae but no puparia on March 19, and larvae and puparia on March 26. They were not present in the soil directly beneath the carcass but appeared to have migrated to locations from several inches to several feet distant before entering it. When collected they were found in cells. They were more plentiful in soil free from roots, and almost all were in the upper one inch. When brought indoors they pupated and emerged within about one week. Of about 200 individuals collected on March 26, 176 formed puparia and 134 emerged. In the out-of-doors location adults were observed on April 9 and they were plentiful on April 20.

These observations confirm the findings of Holdaway & Evans (1930), and show that this species hibernates in the larval stage in the soil. Despite the severity of the winter of 1947–1948 the larvae of this species of fly hibernated very successfully.

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Control of Thrips on Cotton[1]

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Investigations have been continued at the Texas Station in an effort to find an effective insecticide for the control of thrips on cotton. Results of tests reported by Fletcher *et al.* (1947) indicated that DDT sprays and dusts reduced the thrips population, but failed to increase the yield. The tests reported herein were conducted in the Brazos river bottoms and on uplands near College Station during 1947 to determine the effectiveness of different insecticides, as well as the economy of controlling the pest. *Frankliniella tritici* (Fitch) was found to be the most abundant species occurring on cotton during the season.

In normal years, thrips migrate to cotton from weed host plants early in the season, soon after the plants emerge from the soil. This pest may increase to injurious numbers causing malformed plants and losses in stand.

Field Plats and Treatments.—In experiment 1, shown in tables 1 and 2, the plats were arranged in randomized blocks with 4 replicates of each treatment. Each plat was 12 rows wide and of sufficient length to make one-tenth acre. The dusts were applied with rotary hand guns and the sprays with cylinder compressed air sprayers. The first application was made on the appearance of the cotyledonous leaves and before the thrips migrated into the fields from weeds.

[1] Technical contribution No. 1105, Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

Table 1.—The average number thrips per plant and per cent control following treatments as indicated in experiment 1, located in river bottom-field at College Station, Texas.

Treatments	Number Thrips April 17	Days After 1st Application: 6 — No. Thrips	6 — Per Cent Control	8 — No. Thrips	8 — Per Cent Control
Check (untreated)	.01	.09		.39	
1% DDT spray	.01	.00	100.0	.04	89.7
5% DDT-sulphur	.01	.05	44.4	.24	38.5
3% Gamma benzene hexachloride-sulphur	.02	.05	72.2	.05	93.6
20% Chlorinated camphene-sulphur	.04	.01	97.2	.01	99.4
5% Dichloro diphenyl dichloroethane-sulphur	.04	.09	75.0	.22	85.9
3% Gamma benzene hexachloride-5% DDT	.00	.00	100.0	.04	89.7
Tartar emetic spray[1]	.02	.14	22.2	.24	69.2
Minimum significant difference at 5% level					

[1] 2 oz. tartar emetic and 1 lb. syrup to 3 gallons water.
Applications made April 18, 29 and May 13.

Table 2.—The average number thrips per plant and per cent control following treatments as indicated in experiment 1, located in river bottom-field at College Station, Texas.

Treatments	Days After 2nd Application: 6 — No. Thrips	6 — Control	12 — No. Thrips	12 — Control	Days After 3rd Application: 9 — No. Thrips	9 — Control	Seasonal Average — No. Thrips	Seasonal Average — Control
Check (untreated)	5.25		4.62		4.62		3.0	
1% DDT spray	.01	99.8	.69	85.1	1.10	76.2	.37	90.2
5% DDT-sulphur	2.46	53.1	4.49	2.8	4.14	10.4	2.28	29.8
3% Gamma benzene hexachloride-sulphur	.79	92.5	1.16	87.4	2.28	75.3	.87	84.2
20% Chlorinated camphene-sulphur	.05	99.8	.66	96.4	.50	97.3	.25	98.0
5% Dichloro diphenyl dichloroethane-sulphur	4.30	79.5	9.42	49.0	10.96	40.7	5.00	66.0
3% Gamma benzene hexachloride-5% DDT	.29	94.5	1.58	65.8	1.61	65.2	.70	83.0
Tartar emetic spray[1]	2.70	74.3	3.50	62.1	2.95	68.1	1.91	59.2
Minimum significant difference at 5% level							1.75	

[1] 2 oz. tartar emetic and 1 lb. syrup to 3 gallons water.
Applications made April 18, 29 and May 13.

Table 3.—The average number of thrips per plant and per cent control following treatments as indicated in experiment 2, located in upland field at College Station, Texas.

Treatments	Number Thrips April 19	Days After 1st Application: 5 — No. Thrips	5 — Per Cent Control	10 — No. Thrips	10 — Per Cent Control
Check (untreated)	.02	.36		3.38	
5% DDT-sulphur	.01	.32	.0	1.94	.0
3% Gamma benzene hexachloride-sulphur	.01	.18	.0	.32	81.1
20% Chlorinated camphene-sulphur	.01	.02	88.9	.02	98.8
3% Gamma benzene hexachloride-5% DDT-sulphur	.01	.04	77.8	.11	93.5
Minimum significant difference at 5% level					

Applications made April 21, May 2 and 4.

Table 4.—The average number of thrips per plant and per cent control following treatments as indicated in experiment 2, located in upland field at College Station, Texas.

Treatments	Days After 2nd Application				Days After 3rd Application		Seasonal Average	
	5		11		10			
	No. Thrips	Control	No. Thrips	Control	No. Thrips	Control	No. Thrips	Control
Check (untreated)	2.60		15.31		16.42		7.61	
5% DDT-sulphur	2.58	.0	17.69	.0	19.62	.0	8.43	.0
3% Gamma benzene hexachloride-sulphur	.90	30.8	4.19	45.3	8.18	.4	2.75	31.5
20% Chlorinated camphene-sulphur	.25	80.8	3.31	56.8	4.55	44.6	1.63	74.0
3% Gamma benzene hexachloride-5% DDT-sulphur	.35	73.1	6.46	15.6	14.35	.0	4.26	52.0
Minimum significant difference at 5% level							2.20	

Applications made April 21, May 2 and 4.

Table 5.—The average percentage "thrips injured" plants and yields for treatments as indicated in experiments at College Station, Texas.

Treatments	Experiment 1		Experiment 2	
	Per Cent Thrips Injured Plants	Yield, Seed Cotton per Acre	Per Cent Thrips Injured Plants	Yield, Seed Cotton per Acre
Check (untreated)	16.8	1705	6.2	1146
5% DDT-sulphur	8 0	1700	10.2	1225
3% Gamma benzene hexachloride-sulphur	11.5	1613	8.5	1176
20% Chlorinated camphene-sulphur	6.5	1593	5.0	1152
3% Gamma benzene hexachloride-5% DDT-sulphur	7.0	1607	7.2	1270
5% dichloro-diphenyl-dichloroethane-sulphur	7.8	1594		
1% DDT-spray	5.5	1545		
Tartar emetic spray	10.2	1514		
Minimum significant difference at 5% level	5.2	—	—	—

The insecticide dusts were applied to the plants in plats as indicated in table 1, on April 18, 29 and May 13 at an average rate of 12.5 pounds per acre. The sprays were applied on the same date at an average rate of 11 gallons per acre. All plats received applications of 3 per cent gamma benzene hexachloride-5 per cent DDT-sulphur mixture later in the season for the control of weevils and bollworms.

In experiment 2, shown in tables 2 and 3, the plats were arranged in randomized blocks with 4 replicates of each treatment. Each plat was 11 rows wide and of sufficient length to make one-eleventh acre. The insecticide dusts were applied with rotary hand guns as indicated in table 2 on April 21, May 2 and 14 and at an average rate of 11.5 pounds per acre. All plats received applications of calcium arsenate later in the season for the control of the boll weevil.

Records.—The thrips infestation records were made by collecting 20 plants at random in each plat for examination. These plants were immediately placed in suitable containers for transporting to the laboratory. They were examined by striking the tops against coarse hardware cloth above a black background.

The percentages of "thrips injured" plants were determined by examining several hundred plants in each plat.

The percentages of control were calculated by using Abbott's formula.

The aphid populations were recorded but were not sufficiently high to be considered injurious.

Results.—In experiment 1, DDT spray, 20 per cent chlorinated camphene-sulphur, 3 per cent gamma benzene hexachloride-sulphur and 3 per cent gamma benzene hexachloride-5 per cent DDT-sulphur were effective against thrips. The tartar emetic spray, 5 per cent dichlorodiphenyl dichloroethane-sulphur and 5 per cent DDT-sulphur were ineffective. All treatments significantly reduced the percentage "thrips injured" plants, but did not increase the yield.

In experiment 2, 20 per cent chlorinated camphene-sulfur and 3 per cent gamma benzene hexachloride-sulphur gave significantly better control than 5 per cent DDT-sulphur. Even though the thrips population was higher in experiment 2 than in experiment 1, the percentage "thrips injured" plants was lower. This indicates that other factors are probably responsible for this so called "thrips injury." None of the treatments increased the yields.

The 5 per cent DDT-sulphur dust was not as effective against thrips in these tests as in tests conducted during previous years. Apparently the different weather conditions had some effect on the toxicity of this material.

Summary.—DDT spray, 20 per cent chlorinated camphene-sulphur and 3 per cent gamma benzene hexachloride-sulphur were effective in reducing the thrips population. In one experiment, these materials also reduced the percentage injured plants but failed to increase the yield. In the other experiment, these materials did not effect the percentage "thrips injured" plants or increase the yields. Five per cent DDT-sulphur was not effective against thrips during this season.—3-13-48.

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Protection of Workers Applying Nicotine Alkaloid as a Concentrated Mist Spray

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In making emergency applications of nicotine alkaloid with blower equipment for control of the pear psylla, *Psylla pyricola* Foerst., in the Wenatchee Valley, Wash., a number of operators suffered from nicotine poisoning. A report on these difficulties and the methods developed to avoid such poisoning may be of interest to other persons who have occasion to work with this toxic insecticide.

The applications were made to nearly 30,000 pear trees late in the dormant season of 1946–47. A product containing 97 to 99 per cent of nicotine was used in kerosene or water at the rate of 16 ounces of the alkaloid per gallon.

Although no symptoms were experienced by workers who made preliminary tests, many of the operators applying the material on a large scale soon showed signs of poisoning. The individuals most seriously affected had weird dreams, a heavy feeling in the chest, difficulty in breathing, and violent nausea which continued in some cases for as long as 8 to 10 hours. The length of time susceptible individuals could work without becoming ill varied, but was never more than 1 or 2 days. After recovering, they could not work with the alkaloid again without recurrence of the illness. Most of the workers experienced no warning symptoms. With some operators the weird dreams occurred before the nausea, and these workers were immediately replaced. All workers complained of a burning sensation when the nicotine alkaloid spray first came in contact with their faces, necks, and hands. Absorption through the skin seemed to be more detrimental than inhalation of the fumes, although the fumes tended to aggravate the nausea once the nicotine had been absorbed into the system.

The need for precautionary measures was evident, and steps to provide them were taken immediately. Dust-type respirators were tried, with no noticeable benefit. Gas masks equipped with special canisters to filter out the nicotine fumes were found to be effective. The use of rubber gloves and aprons protected the workers from the small droplets of nicotine that splashed onto the hands and clothing during the mixing and tank-filling operations. The spray men were required to take one charcoal tablet an hour and to chew it well before swallowing it. It was believed that the tablets would help to prevent nausea. One commercial operator, who had become violently ill every time he used nicotine alkaloid with oil, reported that he was able to ward off this nausea by taking charcoal tablets.

When the operators first complained of a burning sensation on their faces, necks, and hands, one of the orchardists furnished them with a lanolin type of cold cream that his employees used when applying lime-sulfur sprays. No relief was obtained. Investigation revealed that nicotine is soluble in this type of cream, which may serve as a medium for the introduction of the poison into the body. A protective skin covering in which nicotine is not soluble was found, and this was used to cover all exposed skin surfaces. The operators were also required to keep shirt necks buttoned and sleeves rolled down, to expose as little skin surface as possible, and to change clothes frequently. After these and other precautionary measures described had been adopted, all individuals were able to work with nicotine alkaloid without suffering any discomfort.

The treatment for nicotine poisoning, according to medical authorities (Gonzales *et al.* 1937), is to "evacuate the stomach and administer powdered charcoal to absorb the alkaloid. Gastric lavage with tannic acid and dilute iodine solution is recommended. Warmth, artificial respiration and oxygen inhalation are used to combat shock."

Nicotine is an extremely toxic material, which must be handled with care, but if suitable precautionary measures are followed, its use should prove no more dangerous than that of many other insecticides.—5-2-48

[1] Acknowledgment is made of assistance rendered by the Chelan County, Wash., Board of Health.

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The Leafhopper *Cicadella stellulata* on Cherry

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The leafhopper *Cicadula stellulata* (Burm.) was first reported from Pennsylvania in 1945[1] as a pest on sour cherry. Its occurrence on pear in Europe was noted. At that time it was known only from Connecticut and State College, Pa. Since then it has been taken in light traps from six new localities in

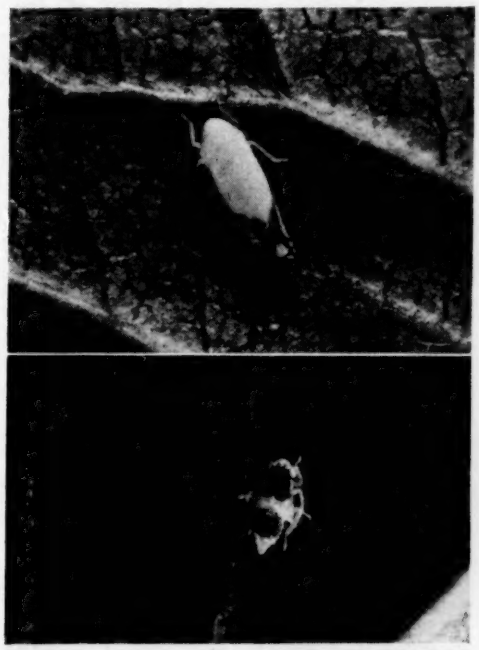

FIG. 1. *Cicadula stellulata*, Adult and Nymph.

Pennsylvania; Philipsburg, Williamsport, Telford, Pottstown, Presque Isle, and Pymatuning. The dates of collections range from June 30 to August 15 although the majority of the specimens were taken during the latter part of July. During the past summer this leafhopper has also been found abundant on Hawthorn at State College. On this host the insects appear along with other common species such as the white apple leafhopper, *Typhlocyba pomaria*, and the injury represents a mixture of several species. On sour cherry the hoppers seem to constitute an almost pure culture. As noted in the previous report, the injury began to appear about the first of July and by early August the leaves showed unmistakable injury. Heavy infestations still occur on sour cherry. The populations average 8 to 10 leafhoppers per leaf with nearly every leaf on the tree showing signs of injury. The leafhoppers feed almost entirely from the lower surface of the leaves. The nymphs are quite inactive. As a matter of fact they remained and developed on foliage severed from the tree for 4 or 5 days. The dark spot on the thorax and a similar one on the abdomen distinguished the nymph of this species from others. The adults on the other hand are very active and readily fly when disturbed. The markings of the rather large milky-white adult are evident in the accompanying photograph.

These observations indicate that *Cicadella stellulata* is apparently not rare but for some reason has been overlooked. The catches from light traps have not been numerous. Usually only three or four specimens were taken during a single night's collection along with thousands of other leafhoppers. The presence of this leafhopper on hawthorn emphasizes the fact that ornamental varieties may serve as reservoirs for the breeding of this as well as other economic insects. The quince curculio and the cherry-hawthorn leaf miner are other well-known examples.—3-7-48.

Control of the Cowpea Curculio

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The injury of the cowpea curculio, *Chalcodermus æneus* Boheman, is a limiting factor in the production of Black Eye peas throughout the Rio Grande Valley of Texas. Arant (1938) recommends dusting with sodium fluosilicate for the control of this insect. Since this material is unavailable locally, preliminary experiments were conducted in order to test the efficiency of the newer insecticides as controls for the cowpea curculio, in comparison with cryolite, which is now being used.

METHODS AND MATERIALS.—The first experiment was conducted on Black Eye peas. The plots were 50 feet long and 12 feet in width. The treatments applied are shown in table 1. Each treatment was replicated three times. The dusts were applied with rotary hand dusters at approximately 25 to 30 pounds per acre. The first application was delayed until some cowpea curculio injury was noticed. Three treatments were applied at 5, 6 and 10 day intervals. Control was determined by examining 100 bean pods in the middle two rows 6 days after the second and third applications.

The second experiment was also conducted on Black Eye peas. The plots were 50 feet long and 18 feet in width. The treatments applied are shown in table 2. Each treatment was replicated three times.

Table 1.—The effectiveness of various insecticides in reducing cowpea curculio infestations on Black Eye peas.

TREATMENTS	PER CENT PODS INFESTED AFTER	
	2 APPLICATIONS	3 APPLICATIONS
5.0% DDT	3.3	0.7
40.0% Cryolite	5.3	1.7
5.0% Chlordan	4.0	2.0
Untreated	15.3	15.6

As in the first experiment, the dust applications were delayed until an infestation became apparent. Two applications of dust were applied at six day intervals. Data were taken in the same manner as in experiment 1, five days after the final application.

The third experiment was conducted in a field of Purple Hull peas. The plots were same in size as those of experiment 1. The treatments are shown in table 3. Each treatment was replicated three times, and applied in the same manner. As in the case of the other experiments, treatment applications were delayed until the infestation was noticed on the beans. A heavy rain fell within a few hours after the first application, so the field was re-dusted 2 days later. A third application was applied 6 days after the second application of dust. Data were taken in the same manner as in the other two experiments, 6 days after the final dust applications.

DISCUSSION.—As mentioned before, the plots in the first experiment received three dust applications. The data in table 1 indicate that cryolite, DDT and chlordan will control the cowpea curculio. Arant (1938) was not able to obtain commercial control of this insect when cryolite was used at the rate of 8 pounds per acre. This difference in degree of control obtained may be partially explained by the fact that approximately three times as much cryolite dust was used in this experiment. The data also show that a 5 per cent DDT dust is slightly superior to the 40 per cent cryolite dust. A 5 per cent chlordan dust proved to be as effective as the cryolite dust, and like DDT, should be investigated further.

The data in table 2 also indicate that cryolite is effective in reducing cowpea curculio infestations. Parathion, used at a 1 per cent concentration, also gave good control. The 5 per cent concentration of dichlorodiphenyl-dichloroethane reduced the infestation greatly but was not as effective as cryolite.

Table 2.—The effectiveness of various insecicides in reducing cowpea curculio infestations on Black Eye peas.

TREATMENTS	PER CENT PODS INFESTED
40.0% Cryolite	2.7
50.0% Ryania	14.7
1.0% Parathion	3.3
1.0% γ-Benzene hexachloride	10.0
5.0% dichlorodiphenyl-dichloroethane	5.7
Untreated	17.6

Table 3.—The effectiveness of various insecticides on reducing cowpea curculio infestations on Purple Hull peas.

TREATMENTS	PER CENT PODS INFESTED
5.0% DDT	2.0
40.0% Cryolite	2.3
1.0% Rotenone	3.0
0.1% Pyrethrins+0.5% DDT (impregnated dust)	3.0
5.0% Chlorinated camphene	0.0
Untreated	4.0

Benzene hexachloride and *Ryania* were of little value as a control for this pest.

The cowpea curculio infestation, as is shown by the infestation records on the check plots, was too low for a good test in the third experiment. However, trends similar to those in experiment 1, are evident. The data indicate that cryolite dustings did reduce the cowpea curculio infestation. As in the case of experiment 1, DDT proved to be slightly superior to cryolite in controlling this insect. A 5 per cent chlorinated camphene gave perfect control of the cowpea curculio, and should be given further trials.

SUMMARY.—The data indicate that applications of 40.0 per cent cryolite, 5.0 per cent DDT, 5.0 per cent chlordan, and 1 per cent parathion were effective in controlling the damage caused by the cowpea curculio on Black Eye peas. A 5 per cent dichlorodiphenyl-dichloroethane dust was almost as effective as the 40 per cent cryolite dust. Chlorinated camphene, used as a 5 per cent dust, was very effective, and should be investigated further as the cowpea curculio infestation was low.

Benzene hexachloride, used at a 1 per cent gamma concentration, and 50 per cent *Ryania* dusts are of no value as a control for the cowpea curculio.

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An Authentic Case of Ox Warble in Man[1]

LEONARD HASEMAN

Entomological literature contains records of a considerable number of cases of myasis in man due to both the ox warbles, *Hypoderma*, and to horse bots, *Gastrophilus*. The descriptions of the different cases indicate that each of these two types of parasites seem to have its own rather definite pattern of attack in man. The case history of an attack by a late first instar larva of *Hypoderma lineatum*, which I wish to discuss here, shows that in this case the parasite followed quite closely its usual pattern of attack.

In the winter of 1945 a letter was received from a correspondent in Charleston, Missouri, asking for information on the habits and identification of a small grub which his son had just squeezed from a boil-like swelling on the back of his head. Upon request for more complete information on the case and the specimen, we received the preserved specimen and a fairly complete description of the progress of the attack from the time that trouble was first noted until the grub was removed from the swelling on the back of the head a month later, in mid-January. For identification the specimen was sent to Dr. F. C. Bishopp of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, and he and Dr. E. W. Laake determined it as a nearly full-grown first instar larva of *Hypoderma lineatum*.

From the description furnished, the trouble began about the middle of December with swelling, stiffness and pain in the middle of the thigh which lasted about a week. Next it appeared in the ankle and calf of the leg with similar pain and swelling for 2 days. Then it moved to the knee for 3 days and on into the upper part of the thigh and the hip, and for a couple of days in the back. Soreness, stiffness and swelling developed at each point though seemingly no marked irritation was caused by the maggot in transit between the points. It then moved to the back of the neck for 3 days and finally to the back of the head for 4 or 5 days before it was squeezed out, following applications of a hot-water bottle. While in the back of the head it caused excruciating pain and by pressing on the swelling a squeaking-like sound was noted, similar probably to that when the warbles on a cow's back are pressed. It was only about 4 weeks from the time real annoyance and pain began until the grub was removed, though undoubtedly it must have been traveling about in the boy's body for some time before he first experienced pain from it.

How, when or where it made its entrance into his body is unknown. He regularly drove the cattle in from the pasture at milking time but did not help milk the cows. He did milk and tend milk goats. Also he usually wore rubber boots while driving in the animals. He unavoidably must frequently have come in contact with the animlals in passing through gates and in the barn which probably gave opportunity for the newly hatched warble grub to get on his clothes and later into his flesh. However it does seem strange that with no more close association with cattle than he had he should have been attacked by one of the warble grubs when thousands of farm boys, men and women milk and tend cattle day after day and are never attacked by this pest. Since infrequent attacks by this pest in man do occur, however, it behooves farmers and others who are regularly associated with cattle to take all reasonable precautions, especially during the period when the warble flies are on wing and ovipositing, to escape contact with the newly hatched larvae.—12-28-47.

[1] Contribution from the Department of Entomology, Missouri Agricultural Experiment Station Journal Series No. 1125.

Effect of DDT on the Green Peach Aphid and Its Coccinellid Predators

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In tests against the green peach aphid, *Myzus persicae* Sulz., and the peach twig borer, *Anarsia lineatella* Zell., on peach trees near Yakima, Washington, in the spring of 1947, some interesting observations were made on the effect of DDT, in comparison with the other insecticides employed, on coccinellid activity.

On March 19, when the peach trees were coming into bloom, about 2 to 3 weeks after all overwintering eggs of the green peach aphid had hatched, various sprays were applied for aphid and twig borer control. Plots of 65 to 80 trees were sprayed with dormant oil containing basic lead arsenate, cryolite, or DDT, and others with nicotine sulfate, hexaethyl tetraphosphate plus DDT, or lime-sulfur. On April 7, at petal fall, three previously unsprayed plots were sprayed with DDT, lead arsenate, and cryolite in tests against the peach twig borer. A portable power sprayer was used to apply all these materials.

On April 23, 900 terminal twigs in each plot were checked for aphid infestation. At this time it was noticed that there were numbers of coccinellid egg clusters and adult beetles, mostly *Hippodamia convergens* Guerin and *Coccinella transversoguttata* Fald., in certain plots and very few in others. Observers counted all the egg clusters they could find on a single large branch on each of 10 trees per plot. Counts of beetles were also made in some of the plots, each observer counting the number found during a 5-minute period.

A summary of the treatments applied and the observations made is given in table 1.

Table 1.—Effect of DDT and other sprays on the green peach aphid and its coccinellid predators.

Treatment (Quantities per 100 Gallons)	Aphid-Infested Terminals	Coccinellid	
		Egg Clusters	Adults
	Per Cent	*Number*	*Number*
Sprays Applied March 19			
Dormant oil 2% plus—			
Basic lead arsenate 3 lb.	17	341	20
Cryolite 3 lb.	15	320	—
DDT 1 lb.	6	28	0
Nicotine sulfate (40 %) ¾ pt.	13	243	—
Hexaethyl tetraphosphate 1 pt. plus DDT 1 lb.	10	5	2
Liquid lime-sulfur 8 gal.	18	226	—
Check (untreated)	—	216	19
Sprays Applied April 7			
DDT 1 lb.	—	0	1
Lead arsenate 3 lb.	—	211	—
Cryolite 3 lb.	—	173	—

From these results it appears evident that, in this test, the DDT-oil and DDT-hexaethyl tetraphosphate combinations gave better control of the green peach aphid than did the other formulations. It also appears that coccinellids were either repelled, or destroyed by the DDT residue, and that oviposition of the few coccinellids that entered the DDT spray plots was reduced. The few egg groups found in the DDT plots contained only 3 to 5 eggs each as compared with 10 to 15 per group in the other plots. On the plots sprayed for control of the peach twig borer the infestation was not high enough to record any results against this insect.—5-12-48.

Factors Involved in Poisoning German Roaches by Exposing Them to Surfaces Treated with Chlorinated Hydrocarbons

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When an insecticide is tested for its toxicity to an insect, three factors, among others, are taken into account as to the efficiency of the toxicant: namely; (1) the minimum dosage for maximum paralysis; (2) the minimum exposure time with the dosage obtained in part 1 for maximum paralysis; (3) necessity of movement over a treated surface for paralysis. In other words, what is the smallest dosage with the least exposure time which will do the most efficient job and can the insect be immobile and still be affected?

These factors will vary with each insect tested and even with the life stage used. The German roach, *Blattella germanica* (L.), fourth instar, sex disregarded, was the test insect. This instar is the most resistant stage to insecticides in the life cycle. Four insecticides, all new organics, were used; DDT, chlordan, benzene hexachloride and chlorinated camphene. All were applied at so many milligrams per 1000 sq. cm., 930 sq. cm. being equal to one square foot.

Throughout the experiments, glass, pint fruit jars of known inner dimensions were used. The test insecticides were dissolved in acetone and the solution was swished around inside the jar until the acetone evaporated leaving a uniform coating of insecticide within the jar. Lids were not used on the jars. Rather a coating of a 50 per cent oil[1]-50 per cent petrolatum solution was applied around the mouth of the jars to keep the roaches confined. The roaches were thus kept in constant contact with the insecticide.

To keep the roaches immobile on a surface treated with an insecticide, they were anesthetized with carbon dioxide. This was accomplished by taking a box and substituting a piece of glass for a lid. A rubber hose from a carbon dioxide cylinder was run into the box. The jars containing the roaches were then placed into the box, the gas allowed to enter, and the atmosphere in the box was kept at a high concentration of carbon dioxide as long as necessary. The glass top was to permit observation of the roaches.

As for the experiments and results obtained in general:

Ten roaches were used to each test jar. Three to six replications of each test were made, depending on the consistency of the tests.

All insecticides were fresh when used. No attempt was made to evaluate the worth of the insecticides days and weeks after applications. The pure gamma isomer of benzene hexachloride was used. The other compounds were technically pure.

More specifically as to the test work:

A. *Minimum deposit required to produce maximum rate of paralysis.*

The layman holds the following conception of insecticides:

(1) Equal concentrations of all insecticides will produce equal paralysis. (2) Increasing the concentration will increase the paralysis rate. However,

[1] Deobase.

each insecticide has a minimum concentration necessary to produce a maximum rate of paralysis. At a lower concentration, the rate of paralysis drops off; at a greater concentration, no appreciable increase in rate of paralysis occurs.

Glass jars were prepared as described above. Various dosages of each insecticide were made up and roaches exposed to each until paralyzed, the rate of paralysis noted at different time intervals depending on the insecticide.

The results of the experiments to determine the minimum dosage of DDT necessary show that between 10 mg. to 1000 sq. cm. and 25 mg. to 1000 sq. cm. seems to be the proper dosage. The curves for 40 mg. to 1000 sq. cm. and 80 mg. to 1000 sq. cm. show very little increase in paralysis. A dosage of 25 mg. to 1000 sq. cm. is sufficient.

The results of the experiments to determine the minimum dosage of chlordan show that between 0.5 mg. to 1000 sq. cm. and 1 mg. to 1000 sq. cm. seems to be the dosage of chlordan necessary. The curves for 5 mg. to 1000 sq. cm. to 10 mg. to 1000 sq. cm. show very little increase in paralysis. A dosage of 1 mg. to 1000 sq. cm. is sufficient.

The results of the experiments to determine the minimum dosage of benzene hexachloride for its maximum rate of paralysis show that between 0.1 mg. to 1000 sq. cm. and 0.5 mg. to 1000 sq. cm. seems to be the proper dosage. The curves for 1 mg. to 1000 sq. cm. and 3.5 mg. to 1000 sq. cm. show very little differences in rate of paralysis. A dosage of 0.5 mg. to 1000 sq. cm. is sufficient.

The results of the experiments to determine the minimum dosage of chlorinated camphene show no sharp drop in rate of paralysis as is found with the three test insecticides. However, the toxicity compares favorably with DDT on constant exposure.

B. *Minimum time of exposure required to produce maximum rate of paralysis with the minimum deposit determined in preceding experiment.*

After determining the minimum deposit of insecticide required to produce maximum rate of paralysis, the next question is, "What is the minimum exposure necessary to produce a maximum rate of paralysis?" Is there a minimum exposure time after which a greater exposure does not increase the rate of paralysis but a lesser exposure definitely decreases the rate.

Glass jars were prepared as described above. The minimum dosages for maximum rate of paralysis for each insecticide as determined in Experiment 1 were applied to the jars and roaches were exposed to these dosages for different time intervals after which the roaches were transferred to clean jars.

The results of the experiments to determine the minimum time of exposure required of DDT show that an exposure time of about 1 hour at 25 mg. to 1000 sq. cm. seems to be necessary. The 80 minute exposure curve is very similar. However, the 15 and 45 minute exposure curves show a definite decrease.

The results of the experiments to determine the minimum time of exposure required of chlordan to produce maximum rate of paralysis with minimum dosage show that somewhere between a 12 and a 20 minute exposure will give the maximum paralysis at 1 mg. to 1000 sq. cm. It was noted that increasing the dosage to 5 mg. to 1000 sq. cm. speeded up the rate of paralysis but not enough to be worth the extra insecticide necessary.

The results of the experiments to determine the minimum time of exposure required of benzene hexachloride show a distinct break between a 5 and a 10 minute exposure which means a 10 minute exposure at 0.5 mg. to 1000 sq. cm. is sufficient. The action is so rapid here that one must stop and realize that only the gamma isomer is being used and that the material is fresh. Residual effect is important as is the fact that technical benzene hexachloride also contains the other four known isomers.

Previous tests where roaches were continuously exposed to chlorinated camphene treatments indicated that the compound might be highly effective. However, as seen here the results of the compound are obvious only at exposure periods greater than 1 hour. The material is either not readily picked up or not readily absorbed in short exposure periods.

C. *Movement over a treated surface as a factor in the paralysis rate.*

When contact between a surface treated with an insecticide and an insect is considered, movement of the insect over the insecticide is usually taken for granted. But is it possible that contact alone will produce paralysis? It was the purpose of these experiments to place both mobile and non-mobile roaches on identical treated surfaces for definite time intervals and then observe the rate of paralysis.

Glass jars were prepared as described above. Two identical sets of jars were made: one for roaches to run on at will, the other for roaches which had been immobilized by carbon dioxide to be laid upon. Roaches in both sets of jars were exposed for a set length of time and then transferred to clean jars. Rate of paralysis was noted at different time intervals depending on the insecticide. Check jars of roaches treated with the gas showed no ill effects at all. Chlorinated camphene was not used in these tests.

The results of the experiments to determine the necessity of movement of roaches over a treated surface of DDT show practically identical results between the mobile and immobile roaches. Thus we conclude that roaches can either pick up some of the insecticide while lying on it or the DDT has some fumigating action. Up to the present, no claim of fumigating action has been attributed to DDT.

The results of the experiments to determine the necessity of movement of roaches over a treated surface of chlordan show practically identical results between the mobile and immobile roaches. There is no doubt here that roaches may pick up a fatal dose of chlordan while lying on it and the curves even point to a possible fumigating action which would possibly be more effective in a carbon dioxide atmosphere. Fumigating action has been claimed for chlordan.

The results of the experiments to determine the necessity of movement of roaches over a treated surface of benzene hexachloride show a tremendous initial rate of paralysis with some recovery after a period of time. The carbon dioxide treated roaches show quite a higher rate of paralysis than those allowed to run freely over the surface. This indicates a possible fumigating effect aided by increased respiration from the carbon dioxide atmosphere. The roaches definitely acquire the insecticide in some manner as the check jars of roaches exposed to carbon dioxide showed no ill effects.

Comparative Effectiveness of Three Types of DDT Dust Mixtures Against Pea Aphids

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In experiments with DDT for control of the pea aphid, *Macrosiphum pisi* (Kltb.), in Wisconsin in 1945, 1946, and 1947, three types of dust mixtures were included in the formulations tested. In the first type of dust the DDT was dissolved in a volatile solvent, in the second type it was dissolved in a nonvolatile solvent, and in the third type it was ground with pyrophyllite before being mixed with talc. Anderson & Brooks (1947) report results of similar experiments in which the second type was the most effective against the pea aphid.

A 5 per cent dust of the first type was prepared as follows: To obtain 60 pounds of dust 3 pounds of technical DDT was added to 2.25 to 2.5 quarts of the solvent (acetone, carbon tetrachloride, or trichloroethylene), depending upon the solubility of DDT in these solvents. The DDT was dissolved by heating in a water bath to near 100° F. The solution was then sprayed, one-quarter at a time, into a revolving mixer containing 57 pounds of talc and some stones. From 10 to 15 minutes were allowed for mixing the first three aliquots. After the last aliquot had been introduced, the batch was mixed for 30 minutes or until practically all of the solvent had evaporated. Acetone was employed as the soovent in 1945, but because of the fire hazard involved a change was made to carbon tetrachloride in 1946. Trichloroethylene became available and was employed in 1947.

The second type of dust was prepared in the same manner as the first, except that the 3 pounds of DDT was added to 2.4 quarts of a commercial nonvolatile solvent consisting chiefly of a mixture of di- and trimethylnaphthalenes.

The third type of dust was prepared from a proprietary mixture containing 10 or 50 per cent of technical DDT ground with pyrophyllite by further dilution with talc.

In all experiments the dust mixtures were applied to approximately 0.25 acre plots of canning peas in replicates of six, by means of a power duster, at the rate of 35 pounds of dust per acre. Results of these experiments are shown in table 1.

In 1945 the dusting was done on June 12, when the infestation averaged 108 aphids per sweep. The dust prepared from DDT dissolved in acetone was significantly superior to the DDT ground with pyrophyllite except on the ninth day after application. Only 5 per cent mixtures were tested.

In 1946 dusts containing other percentages of DDT were included. The dusting was done on June 6, when the infestation averaged 60 aphids per sweep. The dust mixture prepared from DDT in carbon tetrachloride seemed to be consistently better than the ordinary DDT-pyrophyllite mixture even at half the strength. The mixture containing 1.25 per cent of DDT was less effective than the stronger mixtures.

In 1947 the dust prepared from DDT in a nonvolatile solvent was compared with the types of dust previously tested. The dusting was done on June 25, when the infestation averaged 72 aphids per sweep. The dust mixture containing 1.25 per cent of DDT in the mixture of di- and tri-methylnaphthalenes was generally superior to the other three mixtures.

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Table 1.—Control of the pea aphid with three types of DDT-talc dust mixtures—DDT dissolved in volatile and nonvolatile solvents and ground with pyrophyllite.

Stock DDT Preparation	DDT in Dust	Aphids per Sweep Surviving							Average
		1	2	3	6	7	9	16	
		1945 Experiment							
10% in pyrophyllite	5%	22	16	—	4	4	3	—	10
81% in acetone	5	10	6	—	2	2	2	—	4
Difference required for significance at odds of 19:1	—	5	8	—	2	2	[1]	—	3
		1946 Experiment							
10% in pyrophyllite	5%	26	10	—	—	10	—	12	14
30% in carbon tetrachloride	5	21	6	—	—	6	—	6	10
	2.5	17	6	—	—	9	—	7	10
	1.25	28	12	—	—	30	—	23	23
Difference required for significance at odds of 19:1	—	6	4	—	—	8	—	8	5
		1947 Experiment							
50% in pyrophyllite	5.4%	8	13	20	—	—	—	—	14
44% in trichloroethylene	2.5	8	12	21	—	—	—	—	14
	1.25	8	15	26	—	—	—	—	17
54% in di- and tri-methylnaphthalenes	1.25	3	6	12	—	—	—	—	7
Difference required for significance at odds of 19:1	—	4	[1]	9	—	—	—	—	6

[1] Not significant by the F test.

In this test the dust prepared with 2.5 per cent DDT in a volatile solvent was approximately as effective as the ordinary DDT-pyrophyllite dust.

These results suggest that further experiments should be carried out to compare the effectiveness of these and other types of DDT dust mixtures against the pea aphid.

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Effectiveness of Insecticides on the Boll Weevil in Cotton Squares in 1947

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In 1947 several tests were made at Tallulah, La., to determine the effect of various insecticides used as dusts for control of the boll weevil, *Anthonomus grandis* Boh., upon immature stages in cotton squares.

On August 11 cotton squares were collected from the ground in four large plots that had been treated with an insecticide and from an untreated plot. The collections were made after either three or four applications at the rate of about 10 pounds per acre with a 6-row power duster. The squares were examined and classified as follows: (1) Those containing live stages (adults, pupae, and larvae), (2) those containing dead stages, (3) those having empty cells with emergence holes, and (4) those having egg punctures only.

Table 1 shows that squares from the plots treated with dusts containing chlordan alone and with the mixture of benzene hexachloride, DDT, and sulfur had the highest percentages of dead weevils and also the smallest percentages of emergence holes. These results indicate that chlordan and benzene hexachloride greatly affected the development of the boll weevil in the cotton squares.

Cotton squares with boll weevil egg punctures were collected from untreated plants on August 18, and from the ground under untreated plants on August 20, Squares collected from plants usually contain eggs and young larvae, whereas fallen squares contain larvae, pupae, and adults. To test the fumigating action of the insecticides, the squares collected on August 18 were exposed for 21 days in airtight lantern globes to the vapors only or chlordan, benzene hexachloride, chlorinated camphene, or parathion (O, O-diethyl O-*p*-nitrophenyl thiophosphate). The squares collected on August 20 were taken to the laboratory and placed in a dusting chamber where they were given a fairly heavy application of the same insecticides used in the previous tests. After treatment the squares were placed in lantern globes for 19 days. This was a combination contact and vapor, or fumigation, test. In all the tests adult boll weevils were removed from the lantern globes as they emerged from the squares.

The results of these tests are given in table 2. The vapors from the chlordan killed all the developing boll weevils and those from the benzene hexachloride and the parathion killed most of them. The chlorinated camphene did not give off vapors which affected to any extent the development of the immature stages. In the tests in the dusting chamber the chlordan and benzene hexachloride killed all the developing boll weevils, whereas paarthion and chlorinated camphene were less effective.

Table 1.—Condition of boll weevils in cotton squares collected from the ground on August 11 in plots dusted with various insecticides on July 28 and August 1 and 5.

Treatment	Per Cent of Squares Having—			
	Live Stages	Dead Stages	Emergence Holes	Egg Punctures Only
Check (no treatment)	41	3	17	39
Calcium arsenate and Calcium arsenate plus nicotine 2%[1] in alternate applications	27	22	23	28
Benzene hexachloride (gamma isomer 3%)	41	29	7	23
DDT 5%, plus sulfur 40%	41	29	3	27
Chlordan:				
20%	41	29	3	27
3% plus DDT 3%	53	15	8	24

[1] A fourth application on August 9.

After these tests were completed, all the squares were examined to determine which stages were affected by the organic compounds. In the fumigation test the boll weevils treated with chlordan reached the adult stage and died within the squares. In the combination contact and fumigation test both larvae and adults were found dead. The ben-

Table 2.—Boll weevil emergence from cotton squares exposed to vapors only and from squares dusted with various insecticides and then exposed to their vapors.

Treatment	Per Cent of Squares Producing Adult Weevils	
	Vapors Only	Dust and vapors
Check (no treatment)	84	51
Chlordan 20%	0	0
Benzene hexachloride, gamma isomer 5%	4	0
Chlorinated camphene 20%	72	29
Parathion 5%	10	8

Table 3.—Boll weevil emergence from cotton squares collected from the ground in plots dusted four times with various insecticides. Insecticides applied on August 18, 22, and 28, and September 2.

Treatment	Per Cent of Squares from Which Weevils Emerged After Indicated Number of Applications				
	One	Two	Three	Four	Average
Check (no treatment)	75	75	44	35	57
Chlordan 20%	31	8	9	7	14
Benzene hexachloride, gamma isomer 5%	52	57	33	24	41
Chlorinated camphene 20%	66	76	56	53	63
Parathion 5%	80	73	56	—	70

zene hexachloride killed a larger proportion of larvae than of adults.

Beginning on August 18 four heavy applications of four insecticides were made on plots consisting of 4 rows 100 feet long. The insecticides were applied with rotary hand dusters late in the afternoon. From 3 to 5 days after each application cotton squares were collected from the ground in each treated plot and in untreated areas and placed in rearing cages in the insectary until all the weevils in them had emerged.

The percentages of squares collected after each application, from which boll weevils emerged are shown in table 3. At the strengths used, chlorinated camphene and parathion had no effect whatever upon the developing boll weevils in cotton squares, whereas chlordan caused high mortality and benzene hexachloride caused some mortality of the developing weevils.

Control of the Greenbug with Insecticides

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Although the greenbug, *Toxoptera graminum* (Rond.), is one of the most important insects attacking small gains in Oklahoma, little effort has been made to control it with insecticides. A light outbreak of this insect in a field of winter oats near Stillwater, Oklahoma, in the spring of 1947 afforded the writer an opportunity to test some of the newer insecticides on this aphid.

PROCEDURE.—A 25-acre field of Wintok winter oats moderately infested with greenbugs was divided into 18 1-acre plots, with 45-foot strips left between the various plots. Eight plots were treated on March 19, each with a different insecticidal dust, and 8 other plots received identical treatments 9 days later. A check plot was left untreated on each occasion. The air temperature in the shade at the time of the first treatment was 50° F., and during the following 48 hours ranged from 31 to 60°, with an average hourly reading of 46°. The second treatment was made when the temperature was 46°, and during the following 48 hours the temperature ranged from 29 to 67°, with an average of 47°. The dusts were applied at approximately 12 pounds per acre with a 6-row power duster.

Table 1.—Per cent reduction of greenbugs on winter oats at intervals after the application of various insecticide dusts at approximately 12 pounds per acre.[1]

TREATMENT	DAYS						
	1	2	3	7	14	21	28
γ-Benzene hexachloride:							
1%	1	39	41	39	64	59	7
2%	35	69	75	75	69	36	21
3%	72	87	93	96	95	99	92
5%	76	88	95	98	99	99	98
2.5% plus DDT 5%	66	84	89	91	89	85	82
DDT 5%	33	54	47	53	18	34	[2]
Rotenone 1%	[2]	34	38	31	12	[2]	[2]
Hexaethyl tetraphosphate 3%	72	84	89	81	68	64	55

[1] Population in check increased until 21st day and then rap dly decreased.
[2] Greenbug population higher than check.

The following commercial materials were used in preparing the dust mixtures: Cube root powder (rotenone 5.1 per cent, total cube resins 13.0 per cent), 50 per cent benzene hexachloride (gamma isomer 5 per cent), 50 per cent DDT, and technical hexaethyl tetraphosphate. These materials were diluted with talc to the desired concentration before they were applied.

After the plots were staked but before any of the insecticides were applied, a point was selected at random in the plot and marked with a stake. With this stake as the starting point, 100 greenbugs were counted down a drill row and another stake was inserted. Counts were made at 5 such locations. The greenbugs in each of these locations were counted 24, 48, and 72 hours after treatment and at weekly intervals as long as the infestation existed. When the grain was mature, an 8-foot length of drill row at each of these locations in the plots dusted on March 19 was harvested and threshed, and the yield per acre was calculated. No yield data were taken from the second group of plots because they were not on uniform soil.

RESULTS.—The reduction of greenbugs obtained with the different insecticides at various intervals after treatment is given in table 1. In a statistical analysis in which the per cent reduction data at the

Table 2.—Effect of greenbug populations at different times on yield of winter oats.

TREATMENT	GREENBUG POPULATION (NUMBER PER FOOT OF DRILL ROW)			CALCULATED YIELD BUSHELS PER ACRE[1]
	At Time of Treatment	72 hours after Treatment	Highest in Later Observations	
γ-Benzene hexachloride:				
1%	11.9	5.5	40.3	8.7
2%	11.0	4.9	70.4	8.2
3%	36.6	2.8	2.8	12.1
5%	29.3	0.9	0.8	13.3
2.5% plus DDT 5%	37.0	4.5	61.3	9.6
DDT 5%	26.0	11.4	142.3	9.9
Rotenone 1%	16.4	14.0	281.2	6.6
Hexaethyl tetraphosphate	36.4	5.5	108.7	12.5
Check (untreated)	16.5	23.1	152.7	6.5

[1] Difference required for significance at odds of 19:1 = 4.25 bushels.

10 locations (5 in each plot for each treatment) were transformed to angles in degrees, no significant differences were found between the dusts containing 1 per cent of rotenone, 1 per cent of gamma-benzene hexachloride, and 5 per cent of DDT. The 2 per cent γ-benzene hexachloride dust gave significantly better control than these three treatments but significantly poorer than did dusts containing hexaethyl tetraphosphate, 3 and 5 per cent of γ-benzene hexachloride, or 2.5 per cent of γ-benzene hexachloride plus 5 per cent of DDT.

The aphids that were not killed on the plots treated with hexaethyl tetraphosphate reproduced rapidly, and by the end of 14 days the control was no better than that with 2-per cent γ-benzene hexachloride dust and only slightly better than that with 1 per cent. The aphids also increased rapidly in the plots treated with 5 per cent of DDT and with rotenone.

The effect of intensity of greenbug infestation on yield from the first test only is given in table 2. The yield was low even where greenbug control was effective. Plots treated with 3 and 5 per cent of γ-benzene hexachloride and 3 per cent of hexaethyl tetraphosphate gave significantly higher yields than did the untreated check plot. The peak greenbug population was higher than the original infestation on all plots except those treated with 3 and 5 per cent of γ-benzene hexachloride. These two plots had a better stand and throughout the growing period were much more vigorous than any of the other plots. Adult aphids caged on plants in these plots 14 days after treatment were able to start colonies, but since no colonies started from natural infestations were found, the alate female aphids landing on these plots evidently did not remain to feed and reproduce.

SUMMARY.—Dusts containing 3 and 5 per cent of γ-benzene hexachloride applied to winter oats at 12 pounds per acre gave excellent control of greenbugs over a period of several weeks. The initial control with 3 per cent of hexaethyl tetraphosphate and with 2.5 per cent of gamma-benzene hexachloride plus 5 per cent of DDT was also good, but within 3 weeks the infestation was higher on these plots than at the time the insecticides were applied. Dusts containing 1 and 2 per cent of γ-benzene hexachloride, 5 per cent of DDT, and 1 per cent of rotenone gave relatively poor control.

The yields of oats from plots treated with 3 and 5 per cent of γ-benzene hexachloride and 3 per cent of hexaethyl tetraphosphate were significantly higher than the yield in untreated plots.

Persistence of Chlorinated Camphene as a Fleece Worm Larvicide

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Chlorinated camphene was the most promising of six materials tested as fleece worm larvicides at Kerrville, Texas during 1947. Artificially infested sheep were treated with benzene solutions, water suspensions, and emulsions of chlorinated camphene, chlordan, benzene hexachloride, DDT, x-chlorophenothioxin, and diphenyl.

The sheep were infested by implanting the newly hatched larvae of several blow flies, principally *Callitroga macellaria* (F.) and *Phormia regina* (Meig.), on a very small piece of ground beef which had been rubbed into the wool on the animal's rump. On either the second or the third day after implantation, depending on weather conditions and the development of the larvae, the infestation was treated using the method recommended by Rude *et al.* (1945) for the application of their fleece worm remedy. Each of the chemicals was used at a concentration of 2 per cent. In addition, x-chlorophenothioxin was used at 5 per cent, DDT at 7 per cent, and diphenyl at 10 per cent concentrations. Check animals were treated with a solution of benzene plus 0.5 per cent of Duponol G (an oil-soluble alkyl sulfate), the wetting agent used in all the benzene solutions except the 10 per cent diphenyl.

Approximately a week after treatment an attempt was made to reinfest the sheep by implanting newly hatched larvae in the treated wool in the manner by which the original infestation was established. If the larvae did not become established, the implantation was repeated a few days later and the process was continued until a successful implantation was made or until the tests were discontinued.

Eight of the 10 sheep treated with chlorinated camphene were protected against reinfestation for the entire time they were in test, 55 to 82 days. During this period 10 to 17 implantations of newly hatched larvae were made on each animal. Of the 2 sheep which became infested, 1 resisted 10 implantations made during a period of 63 days and the other resisted 6 implantations during 46 days.

Chlordan and the gamma isomer of benzene hexachloride (83+ per cent pure) protected sheep against reinfestation for relatively long periods of time, but in these tests neither remained effective as long as chlorinated camphene. Two per cent concentrations of DDT, mixed isomers of benzene hexachloride, x-chlorophenothioxin and diphenyl, a 7 per cent concentration of DDT a, 5 per cent concentration of x-chlorophenthioxin, and a 10 per cent concentration of diphenyl were even less effective.

Nine check animals were included in the tests. Of the 105 implantations made on these sheep, 88 were successful.

There was no external evidence that any of the animals were affected adversely by any of the treatments.

These tests were preliminary in nature, and considerable field work is needed to determine the practical value of chlorinated camphene as a fleece worm preventive and to establish definitely the relative effectiveness of the other chemicals. However, it seems possible that the application of this insecticide early in the spring might serve the same purpose as the present practice of "tagging" or shearing wool from the crotch area.—2-23-48.

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Insecticidal Properties of Elemental Fluorine

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Elemental fluorine, F_2, has only recently become available as a compressed gas,[1] and in view of its unusual properties, it seemed of considerable interest to study the material as an insect toxicant. Fluorine is the most reactive of all the elements and combines with nearly every material under suitable conditions. Most of these combinations occur spontaneously at room temperature with consequent combustion. Hence the material is difficult to handle and possesses dangerous toxicity to warm blooded animals. However, using adequate precautions the gas can be safely handled in the laboratory and in the field. Elemental fluorine has a molecular weight of 38, a specific gravity of 1.31 as compared to air, and weighs 0.106 pound per cubic foot. It has a rather disagreeable odor resembling a mixture of ozone and chlorine. The gas is very corrosive, reacting with moisture in the air to form hydrogen fluoride which attacks glass and most metals. It is approximately as toxic as chlorine to mammals.

Data on the physiological effects of exposure to elemental fluorine are very limited and we have been unable to find any reference to its effects on insects, although Marcovitch (1942) and Roark (1943) have commented on the fumigant possibilities of certain volatile fluorine compounds.

The fluorine used in these experiments was obtained from a half pound steel cylinder of the compressed gas[2] and was piped through a needle valve and a section of copper tubing[3] into the fumigation chamber. This latter was a 100-cubic foot stainless steel vacuum fumigation vault, equipped with thermostat and circulating fan to maintain a constant temperature of 20° C. The fluorine was admitted after drawing a vacuum of 5 cm. of mercury in the chamber, and then air was admitted to atmospheric pressure. The dosage was determined by weighing the cylinder before and after the gas was discharged. The results obtained in a one hour exposure on several species of insects, and on *Citrus* seedlings are given in the table. From these data, the effective insecticidal concentration would seem to lie between 100 and 1000 p.p.m., with this latter being above the upper limit as far as plant injury is concerned. For comparative data hydrogen cyanide gas at 1000 p.p.m., at 20° C. kills about 97 per cent of California red scale under similar conditions (Lindgren, unpublished) while the same dosage in a five hour exposure at 25° C. killed 99 per cent of *Tribolium confusum* Duv. (Shepard, *et al.* 1936). Therefore, F_2 appears to be about as toxic to these insects as is hydrogen cyanide.—2-23-48

Table 1.—Effects of fluorine gas on insects.

Species Stage	How Exposed	Mortalities at Indicated Dosage of Fluorine	
		227 p.p.m. 1 g./100 cu. ft. 1 hr.	1305 p.p.m. 5.75 g./100 cu. ft. 1 hr.
Oncopeltus fasciatus (Dall.) adults	screen cages	42%—24 hr.	100%—24 hr.
Blatella germanica (L.) adults	screen cages	0%—24 hr.	73%—24 hr.
Drosophila melanogaster Meig. adults	screen cages	100%—24 hr.	100%—24 hr.
Heliothrips haemorrhoidalis (Bouche) adults	oranges in open glasses	22%—24 hr.	100%—24 hr.
Paratetranychus citri (McG.) adults	oranges in open glasses	78%—24 hr.	100%—24 hr.
Paratetranychus citri (McG.) eggs	grapefruit	14%— 7 days	24%— 7 days
Tribolium confusum Duv. adults	open petri dish	—	81%—24 hr.
Aonidiella aurantii (Mask.) adults	grapefruit	7%—21 days	96%—21 days
Carpophilus hemipterus (L.) eggs	open petri dish	50%— 6 days	80%— 6 days
Citrus seedlings—18″ high	open pot	no effect— 21 days	Slight tip burn 24 hr., all leaves withered in 10 days.

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[1] Ing. Eng. Chem. Vol. 39, 236–88, Symposium on Fluorine. 1947.

[2] Supplied through the courtesy of Mr. W. M. Lee, Special Products Div. Penn. Salt. Mfg. Co.

[3] Manual F-1, Penn. Salt. Mfg. Co. Aug. 1946.

Gynandromorphism in *Aëdes canadensis*

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While making hand collections of mosquitoes attempting to bite, with the aid of an aspirator, in a

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woodland near the Edison Memorial Tower at Menlo Park, New Jersey during the morning of May 10, 1947, a gynandromorph of *Aëdes canadensis* (Theobald) was captured. While the mosquito was flying near the writer's hand it was recognized as an aberrant specimen and was captured before being allowed to alight. It was persistent in seeking a place to alight on the exposed hand and in this respect did not differ from normal female *A. canadensis* caught while attacking the writer.

This aberrant specimen has the following pertinent characteristics: typical female antennae and palpi; legs and wings resemble those of normal male, being more slender than analogous female structures; shape of abdomen and basal white bands as in typical male; lateral abdominal ciliation long, dense on segments 6, 7 and 8, but considerably less dense on basal segments than in normal male; genitalia typically male. The specimen has been deposited in the United States National Museum.

A Technique for Mounting Ectoparasites

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The methods generally available for preparing ectoparasites for classroom work are not too satisfactory. A method is herewith described that has given excellent results in our laboratory. The principal parasites encountered in this region have been studied in order to ascertain the fundamental characteristics used in their identification. This method was then developed by combining the salient features of several recommended techniques that will produce slides suitable for classroom work.

The specimens are carefully removed from the host to prevent the loss of appendages and mouth parts. They are immediately placed in a mixture composed of 97 parts of 20 per cent alcohol and 3 parts of ether. This is a good killing agent and the legs remain extended after death (Boardman 1944).

The actual decolorization, staining, and mounting may be divided into nine steps:

1. The specimens are placed in 10 per cent potassium hydroxide (Salmon & Stiles 1900). They should remain in this solution until all the color has disappeared in both the body and legs. Better results are obtained if the solution is used cold than if heating is employed. The vials are maintained at room temperature, at approximately 70–80° F. The decolorization process varies with the specimen, degree of engorgement and amount of pigmentation present. Lice require about 24 hours while engorged female ticks may require up to a week.

2. The potassium hydroxide is removed by two or three changes of tap water with an immersion of 12 hours in each change.

3. Alcohol series of 40 to 50 per cent are next used. The specimens should remain in each for 60 minutes.

4. The stain consists of a saturated solution of pyrogallic acid in 60 per cent alcohol (Mayer 1937). Best results are obtained where the solution is made up and allowed to stand until it begins to turn brown. The color of the specimen is directly influenced by the duration of exposure to the pyrogallic acid solution. If a light tan specimen is desired, an exposure of 6 to 8 hours is sufficient. An exposure of 24 hours will produce a brown color.

FIG. 1. *Rhipicephalus sanguinens* Latr.

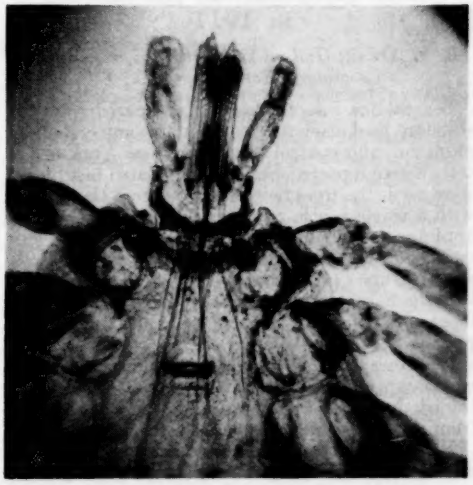

FIG. 2.—*Amblyomma maculatum* Koch.

5. The specimens are washed in two or three changes of 70 per cent isopropyl alcohol for 30 minutes in each change to remove the excess pyrogallic acid and debris.

6. A series of 80, 95, and 100 per cent ethyl alcohol are next. The specimen should remain 1 hour in each change.

7. Carbo-xylol is used to remove the air and moisture that may be present. Carbo-xylol solution is made by the addition of 5 grams of phenol crystals

to 50 cc. of xylol. The specimens should be allowed to remain in this solution for 2 hours.

8. Three changes of xylol are employed to remove any trace of moisture that may remain.

9. The specimens are mounted in *Diaphane* or *Euparal*. Green *Euparal* has been used to bring out some particular structure. There should be no pressure applied to the cover slip in order to prevent distortion of the specimen. After the specimens are mounted in these media they will present a smoky appearance, but this disappears in a few minutes.

Figures 1 and 2 show representative specimens of *Rhipicephalus sanguineus* and *Amblyomma maculatum*. The characteristic structures generally used in the identification of these ticks are clearly shown. Preparations of this type are not always suitable for species identification but they are extremely valuable in acquainting the student with important generic characteristics.

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Plum Curculio Control with Chlorinated Hydrocarbon Insecticides in 1947[1]

R. W. DEAN, *Hudson Valley Fruit Investigations Laboratory, Poughkeepsie, N. Y.*

Several new insecticides were compared with the standard lead arsenate treatment recommended for plum curculio control in eastern New York in the tests herein reported. Solid, unreplicated test blocks were used, the trees being sprayed from the ground with a single-nozzle gun. Applications to Cortland apples were made in the calyx spray (May 28), curculio or 7 to 10 day spray (June 4–5), and first cover spray (June 12). An additional application of benzene hexachloride was made June 18. All treatments included *Micronized* wettable sulfur at 6 pounds per 100 gallons in the calyx and curculio sprays and at 5 pounds per 100 gallons in the first cover spray. The materials used and results obtained, based on examination of all mature fruit from seven trees in each plat, are shown in table 1.

Reduction of fruit scarring was greatest with 50 per cent chlordan wettable powder at 3 pounds per 100 gallons. At 4 pounds and 2 pounds per 100 gallons, chlordan was slightly less effective, but not significantly so. Chlordan emulsion, at 1 pint per 100 gallons, gave less control but the difference between it and the comparable dosage of wettable powder (Plat 5) just escapes significance. A combination of 2 pounds of lead arsenate and 2 pounds of 50 per cent DDT wettable powder per 100 gallons, as suggested by Whitcomb (1947), reduced injury almost as much as chlordan powder and is less expensive. The methoxy analog of DDT, at 2 pounds of 50 per cent wettable powder per 100 gallons, was also effective in controlling curculio. The standard lead arsenate schedule did not give satisfactory control but the addition of a polyethylene polysulfide sticker increased control significantly. A combination of lead arsenate and benzene hexachloride was slightly but not significantly superior to lead arsenate alone. Three pounds of 50 per cent benzene hexachloride wettable powder (6 per cent gamma isomer) per 100 gallons gave no significant reduction in injury over the check.

Table 1.—Control of plum curculio on apples, 1947.

Plat No.	Material	Amount per 100 Gal.	Per Cent Injury
1	Methoxy analog of DDT[1]	2 lbs.	6.11
2	Chlordan[1]	4 lbs.	2.90
3	Lead Arsenate	2 lbs.	4.67
	DDT[1]	2 lbs.	
4	Chlordan emulsion[2]	1 pint	15.09
5	Chlordan[1]	2 lbs.	4.57
6	Chlordan[1]	3 lbs.	1.97
7	Lead Arsenate	2–3 lbs.	22.48
	Benzene Hexachloride[1]	2–3 lbs.	
8	Lead Arsenate	3 lbs.	
	Polyethylene polysulfide sticker[3]	1 pint	6.71
	Hydrated Lime	3 lbs.	
9	Benzene Hexachloride[1]	3 lbs.	53.06
10	Lead Arsenate	3 lbs.	25.70
	Hydrated Lime	3 lbs.	
11	Control		61.22
	Least significant difference at 5% level:		12.36
	Least significant difference at 1% level:		16.44

[1] Containing 50% technical grade material in wettable powder form.
[2] Containing 1 pound of technical chlordan per pint.
[3] *Good-rite P.E.P.S.*

A similar series of tests was made on Hale Haven and Elberta peaches. Treatments were started at the shuck-fall stage (May 29). The standard acid lead arsenate spray was limited to this one application. A second application of all other materials except benzene hexachloride was made June 9, and a third application of methoxy analog of DDT and chlordan was made June 18–19. Benzene hexachloride was applied four times at weekly intervals, starting at shuck-fall, with the last spray going on June 18. As in the tests on apples, *Micronized* wettable sulfur was used in all applications. The results, based on examination of all drops and picked fruit from seven trees in each plat, are shown in table 2.

Chlordan was again the most effective material tested in reducing injury, both the emulsion and the wettable powder giving good control. Methoxy analog of DDT was somewhat less effective although the control obtained was not significantly poorer than that given by chlordan. Benzene hexachloride gave essentially the same control as 4 pounds of chlordan powder per 100 gallons. As pointed out by Driggers (1948), benzene hexachloride, at the concentrations ordinarily used, does not kill the adult curculio and, consequently, there is relatively less reduction of fruit scarring, control being manifested by reduction of the number of wormy drops. As shown in table 2, the percentage of wormy drops was least in the benzene hexachloride plat while the percentage of scarred fruit was greatest. Since plum curculio injury to apples in the Hudson Valley area is primarily in the form of fruit scarring, the apparent lack of control with benzene hexachloride when applied to apples may be explained, in part, at least,

[1] Journal Paper No. 755, New York State Agricultural Experiment Station, Geneva, New York (March 18, 1948).

Table 2.—Control of plum curculio on peaches, 1947.

PLAT NO.	MATERIAL	AMOUNT PER 100 GAL.	PER CENT INJURY WORMY	PER CENT INJURY SCARRED	TOTAL
1	Methoxy analog of DDT[1]	2 lbs.	6.91	0.37	7.28
2	Chlordan[1]	4 lbs.	2.64	0.73	3.38
3	Chlordan emulsion[2]	1 pint	3.60	0.76	4.37
4	Chlordan[1]	2 lbs.	4.15	0.61	4.76
5	Acid Lead Arsenate Hydrated Lime	2 lbs. 16 lbs.	19.60	0.74	20.34
6	Basic Lead Arsenate Hydrated Lime	4 lbs. 4 lbs.	18.38	1.02	19.40
7	Benzene Hexachloride[1]	3 lbs.	1.48	1.98	3.46
8	Control		19.01	1.23	20.23
	Least significant difference at 5% level:		5.36	0.78	5.49
	Least significant difference at 1% level:		7.17	1.05	7.35

[1] Containing 50% technical grade material in wettable powder form.
[2] Containing 1 pound of technical chlordan per pint.

by its mode of action on the insect. Differences in the amount or persistence of spray deposits on peach fruits, as compared to relatively smooth apple fruits, may also play a part.

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OBITUARIES

Cecil Cline Wilson, 1896–1948

The sudden death of C. C. Wilson following a heart attack at his home in Sacramento, California, on Sunday morning, March 7, came as a great shock to his many friends and fellow workers.

Mr. Wilson was born on a grain farm near La Cross, Rush County, Kansas, on February 4, 1896, one of six children of James H. and Sylvia Wilson. His boyhood was spent on the farm where he worked with his father and became thoroughly familiar with general farming and farm practices. This knowledge was invaluable in his later entomological work.

Mr. Wilson attended the local grade school and high school in Canton, Kansas, being graduated from the latter in 1917. He taught in the grade school at Enterprise, Kansas, for one year after graduation. He enlisted in the Marine Corps in June of 1918, where his familiarity and proficiency with firearms earned him the rating of sharpshooter.

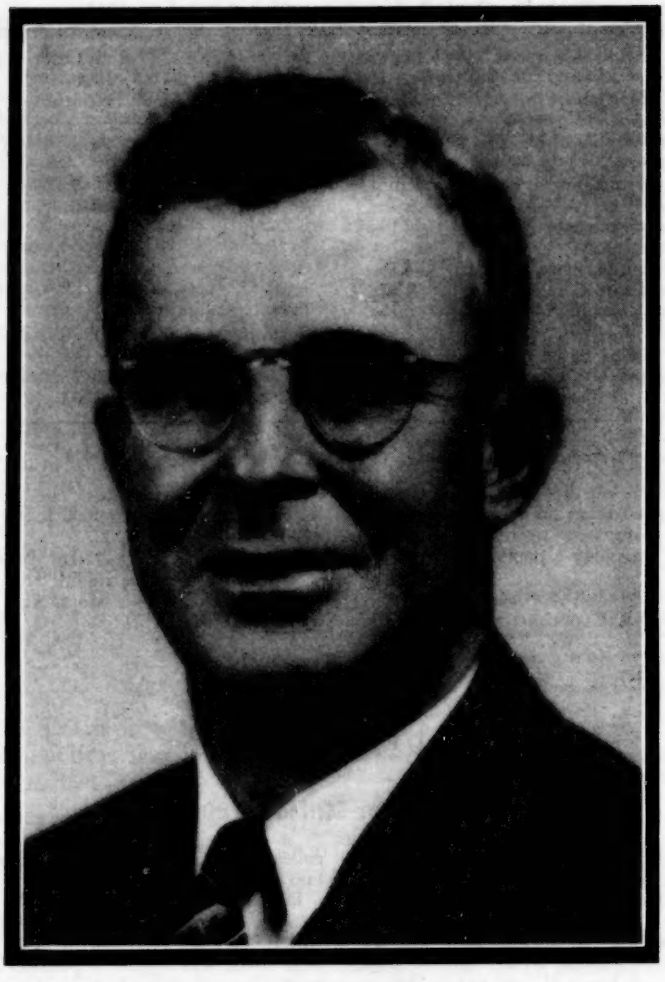
Following his discharge in 1919 he entered Kansas State Agricultural College earning his degree in entomology in May of 1924. By attending summer school and carrying extra courses, he completed most of the requirements for his M.S. by the end of June of that same year. While a student he had many extracurricular interests; he was affiliated with the Phi Sigma Kappa fraternity, and was active in the Purple Masque Dramatic Society where he not only participated in the club's productions but also acted as a coach of dramatics.

In August of 1923, while still in college, he was married to Ruby Thelma Morgan at her home in Manhattan, Kansas. During the remainder of his college career, both he and his wife worked to enable him to continue his education.

During this period he passed the examination for position of Junior Entomologist with the Bureau of Entomology, U. S. Department of Agriculture and as a result was offered a position at the Bureau's Sacramento, California field station. He accepted the offer and on June 30, 1924, moved to Sacramento, where he remained until his death.

As a research entomologist with the U. S. Department of Agriculture, which position he held at the time of his death, Mr. Wilson was a tireless worker and was recognized as the leading authority in California on grasshopper behavior and control. For many years he gave unhesitatingly of his time and knowledge, far beyond the call of duty, in solving the problems in connection with, and assisting in, the control of periodic outbreaks of grasshoppers in California and Nevada. Much of the success in grasshopper control in those states is due to his efforts and to his splendid cooperation with other federal officials and with personnel of state and county agricultural departments.

His research activities were outstanding and the methods of grasshopper control with baits, and more recently with the new organic insecticides particularly applicable to California conditions, worked out by him have resulted in savings to growers totaling many hundreds of thousands of dollars. He was the author of a number of papers which have added materially to our knowledge of the grasshopper problem. Most of his published work appeared in THE



CECIL CLINE WILSON

JOURNAL OF ECONOMIC ENTOMOLOGY and the *Monthly Bulletin* of the California Department of Agriculture. His most recent article "Research on New Insecticides for Grasshopper Control" appeared in the latter publication. He recently had been honored by election to the presidency of the California Entomology Club with which organization he had long been prominently affiliated.

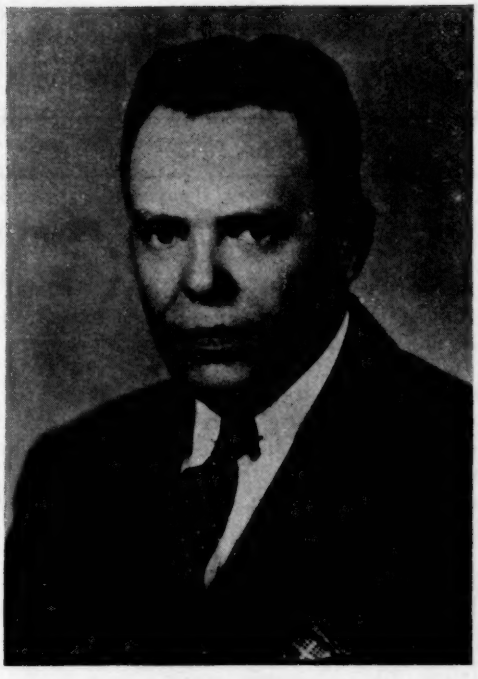
For many years he was a member of the American Association for the Advancement of Science and at the time of his death was a member of the American Association of Economic Entomologists and the Entomological Society of America.

Mr. Wilson participated in many activities outside his professional work. For 25 years he was a member of the Masonic Lodge at Canton, Kansas, and was a Deacon of the First Christian Church in Sacramento. He served for several years on the Inter-Church Council of Sacramento; for many years, and at the time of his death, he was Director of the Youth Recreation Program sponsored by the Council; he organized winter basketball and summer soft ball leagues under their program. He was interested in Boy Scout work and was Scout Master of a Sacramento troop for several years. After he gave up his troop he was examiner in ornithology for the Boy Scouts and conducted many field trips to acquaint the boys with the birds of the Sacramento area. He was well versed in and lectured on the rocks, grasses and flowers of California, and for many years judged these classifications at the Annual California State Fair, as well as in many school exhibits. He was an ardent photographer and his collection of pictures of native flowers and insects is outstanding.

Mr. Wilson or "Stubby" as he was affectionately known to all who were associated with him, was an enthusiastic devotee of hunting and fishing and organized numerous trips for his many sportsman friends. In fact, there were so many interesting and likeable facets to his character that it is difficult to single out any one trait. We have lost not only a scientist but a true friend and a loyal comrade.

In addition to his widow, Ruby M. Wilson, he is survived by two sons, James W. and Allan K. of Sacramento; by his mother, three brothers and two sisters who reside in Central and Eastern States.

W. B. NOBLE
EARLE T. GAMMON



LOYD W. BRANNON

Loyd W. Brannon, 1900–1948

Loyd W. Brannon was born in Shelby, Tennessee, May 30, 1900, one of twin boys. He entered the Mississippi A. and M. College in 1917 and received his B. S. Degree in 1921. Before graduation he was employed as a field assistant, during 1919, on the project for the prevention of spread of the Mexican bean beetle, for the Bureau of Entomology, U. S. D. A., at Birmingham, Alabama. Upon graduation he received a full-time assignment on the same problem. Later he was transferred to the research work on the control of the Mexican bean beetle, and was engaged continuously on this and other bean insect problems until his death, February 23, 1948, except for a period of a few months spent in commercial work. In 1929 he was transferred to Virginia with headquarters at the Virginia Truck Experiment Station at Diamond Springs, Virginia. Loyd was always a conscientious worker and had the grower's interest at heart. Any schedule which was necessary to do a certain job was satisfactory with him. During the war he successfully carried on his research program in addition to insect survey work in connection with the distribution and reallocation of scarce insecticides. For this he was cited for meritorious service and was rewarded accordingly. He was interested in people and was always solicitous of the personal well-being of his friends. He was the author of 26 papers on various phases of the Mexican bean beetle problem and other vegetable insects. His latest published work, over which he was very enthusiastic, dealt with the use of the piperonyls as synergists for rotenone root powders. He developed a combination treatment for the Mexican bean beetle, the corn earworm, red spider, and mildew which was successful. He leaves a wife, Leila, and two children. His many friends grieve at his untimely death.

NEAL F. HOWARD

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Are Foreign Plant Quarantines Worth While?[1]

Foreign Plant Quarantines are designed to safeguard this country against the entry of all undesirable plant pests. These discussions, however, will be limited to insect pests. What may be said about them will also apply to plant diseases. The Division of Foreign Plant Quarantines or a recognizable facsimile thereof has been in existence since the passage of the Plant Quarantine Act 36 years ago. From its inception the Division has operated on the theory that "An ounce of prevention is worth a pound of cure." Unfortunately, preventive measures seldom produce tangible results. It is difficult, therefore, to appraise their worth. Who can say, for example, how many cases of smallpox are prevented by community wide vaccinations? In our case, however, we may compare the incidence of alien plant pest introductions before and after quarantine protection became operative. The information thus gained should indicate whether or not Foreign Plant Quarantines are earning their keep.

To this end, let us examine the past and ascertain what contacts with civilization have brought to the agriculture of this country. This examination will reveal, for example, that our plant culture is largely a borrowed one. Practically no plant we cultivate extensively is native to our soil. This is important when we recall that nature, given time, will often adjust the relationship between a native plant and its pests so that a plant may thrive despite the endemic plant pests which may attack it.

Suppose for the moment our forefathers had found this country with a self-contained agriculture—one that was indigenous to the land, one in which plant and pest relationships had been stabilized. Then our current periodical pest surveys might well be reduced to a one line statement and our annual crop losses estimated in millions rather than billions of dollars. Such, however, was not the case. True the first colonists did find in America a primitive agriculture centering around corn. Even this plant so generally assumed as typically American is botanically speaking a displaced person. Its native habitat is Central America; not the America in which we live. So from the start our founding fathers were forced to accept and supplement our crop producing cultures from outside sources. Moreover, our country, ere it reached its full stature, found itself endowed with a combination of soils and climates acceptable to the plants of the world. Yankee drive saw to it that these plants had their opportunity for a new life in a new land. From these circumstances was fabricated the cloth from which our agricultural economy was cut. Into this cloth was woven a design for a better life; not only for ourselves but unfortunately as it turned out for the plant pests of the world as well.

As we trace that part of the design which depicts the activities of our present day insect pests, we find they come from two sources. First, some of our crop losses are caused by our native insects which have strayed from the ways of their ancestors. In their original environment, these insects were harmless, content to live on native plant life of no significance to man. Their limited food supply even served to reduce their number; because theoretically no mother wants to bear children only to see them suffer privation and death. The new agriculture our forefathers brought to this country altered this situation. With this change our native insects with plebian appetites had their chance at a finer fare—the newly introduced crops of the colonists. What happened is a matter of record. Note, for example, the fate of our potato culture

[1] Annual address of the President of the Texas Entomological Society, San Antonio, Texas, March 11-12, 1948.

when it ran afoul of the Colorado potato beetle. Consider, too, what happened to corn and the small grains once the chinch-bug had sipped their juices and found them to its liking. There are others of this stripe. We are, however, powerless to divert them from their adopted hosts. Like today's laboring classes, these pests have consolidated their gains and are not disposed to return to the lower living standards of other days.

Our plight would have been tolerable could we have limited our crop losses to those inflicted by our native insects. From the toll they exact must, however, be added the burden imposed by a second group, the introduced species. We of the Division of Foreign Plant Quarantines think of this group as falling into two categories. In the one, we place those that are unknown or mildly regarded as plant pests in their fatherland. Undoubtedly parasites, food limitations, or other ecological factors contrive to suppress them in their natural environment and thus contribute to the anonymity they enjoy. Transplanted and freed of these inhibiting factors, they become the fellow traveler of the insect world. Once in a new country they straightway set about wreaking havoc on any crop they find to their liking. Losses traceable to this group have weighed heavily on our agriculture. The San Jose scale, freed of its parasites and predators, was introduced into California about 1876. Before remedial measures brought this insect under control, it had all but bankrupted our fruit growers.

Obscure, too, was the life of the cotton boll weevil in 1843, as it eked out a hand to mouth existence among the wild cotton plants around Vera Cruz, Mexico. Obscurity though need not be a continuing state of being. The boll weevil demonstrated this truism when in 1892 it crossed the Rio Grande and attacked our cotton fields. Since then it has left a path of destruction which by comparison makes General Sherman's famous march to the sea look like a bush-league operation. Humble as was his lot this insect has lived to have its accomplishments fabled in song and story. His depredations have even given birth to a confused logic which proclaims the advent of the boll weevil as a blessing in disguise. This logic even credits the weevil with saving southern agriculture. The arguments used fail to impress me. Admittedly, adversity tempers character, stimulates initiative, and otherwise contributes to a better society. But to say it was a happy occasion when our farmers found one bale of cotton where two were wont to grow sounds off key to me. Surely the benefits some credit to the boll weevil could have been secured at less sacrifice than the one hundred million dollar retainer fee that this insect annually demands from Texas farmers. Unless solving a problem the hard way has some mysterious merit not now discernible to me, it would seem a sounder economy if our farmers were spared the perennial losses the boll weevil inflicts. This might well have been accomplished had we had an effective quarantine service in 1892. We knew as early as 1880 that the weevil was doing serious damage to cultivated cotton in the Monclova district in Mexico. We were forewarned and under different circumstances might have been forearmed.

There are other insects in this same category—the Japanese beetle and the alfalfa weevil, for example, but the two dwelt upon will serve to illustrate our point.

More conspicuous in the annals which recite our crop losses are insects in the second category. These are immigrant insects notorious as crop pests long before they reach our shores. In spite of their unsavory past these undesirables were long accepted by us with open-armed indifference. From this distance, it seems inconceivable that we should have been so unconcerned about the threat they posed. Dr. Howard in his "History of Applied Entomology" brands our complacency as a combination of ignorance and inertia. Events as chronicled by our mid-nineteenth century entomological history seem to sustain this allegation.

Up to 1850 few field insects of serious import had managed to establish themselves in this country. As far as can be ascertained, the Hessian fly and the codling moth were the two alien plant pests of first rank here before that date. Then something happened to hasten the spread of the world's plant pests. This something was undoubtedly the steam boat. Until Fulton's Folly came of age, time was in our favor. Few insects other than those attacking stored products could survive the time consuming voyage

of the old sailing vessels. Improved transportation removed this barrier and the stage was set for the mass-like migration of plant pests which swarmed to our shores during the last half of the nineteenth century.

Though we were unmindful of the changing conditions, other nations were not. As early as 1859 some European countries were framing legislation against pest laden commodities from this country. In 1881, California took the bull by the horns and initiated legislative measures aimed at excluding plant pests from its borders. Our national attitude, however, remained passive until well past the turn of the century. It were as if we had reversed Pinckney's famous ultimatum and had committed ourselves to the policy of "Millions for tribute but not one cent for defense."

Even as late as 1909, long after it was painfully apparent we must do something about foreign pests, Congress remained unimpressed and for three precious years fiddled with the idea of enacting needed legislation. Meanwhile alien pests seemed to sense that time was short; for according to Dr. Howard this brief period of indecision witnessed the arrival of such top notch pests as the European corn borer, the Japanese beetle, the oriental fruit moth and several other significant plant pests. All told we put out the welcome mat for some 30 top ranking economic plant pests during the half century we toyed with the idea of framing a defense against their inroads. It was an era fraught with golden opportunities to prove the worth of preventive entomology but we failed to make the most of the situation.

This in a sketchy way reviews our past experiences with insect pests and brings us up to 1912, the effective date of the Plant Quarantine Act. As soon as the Act became operative the Secretary of Agriculture immediately promulgated quarantines against the then most menacing foreign plant pests. At first, we took action only after a pest had gained world wide notoriety as a crop pest. We operated on the simple principle of barring a pest by banning its host. This took care of the known pests but provided no safeguards against the unsuspected pest. Quarantines 37 and 56 promulgated in 1919 and 1923 respectively remedied this situation.

From then on the Division of Foreign Plant Quarantines was weaned from the parental concept of reckoning only with the known pest. Transformed too was our defensive attitude toward the few pests. This was replaced with a declaration of total war against all foreign plant pests. No longer were plants, fruits and vegetables not prohibited by special quarantine granted the freedom of a port. Instead these commodities entered under parole, tolerated only so long as our inspection did not reveal they were consorting with plant pests harmful to our agriculture. Evidence to the contrary warranted placing a commodity on the black list. Once there a commodity entered, if at all, only after it had been given a safeguarding treatment.

This in brief is the formula now employed by Foreign Plant Quarantines. With what results? Five major plant pests have gained a foothold in this country during the 36 years in which the Plant Quarantine Act has been operative. Of these four have survived. The five are: the white fringed beetle, the Dutch elm disease, the Mediterranean and Mexican fruitflies, and the pink bollworm. Even without an alibi this record compared with the past offers an eloquent defense for quarantine. No one who carefully studies the problem claims plant quarantine offers an unbreachable defense against the introduction of all insect pests all of the time. Errors of omission are bound to creep into any sustained strategy. Moreover any strong flying insect once it secures a foothold in a contiguous country will, conditions being favorable, eventually establish itself within our borders.

In the light of these admissions, let us examine the circumstances surrounding the entry of the insects mentioned above. The white-fringed beetle and the scolytid which serves as a vector of the Dutch elm disease, each employed the Trojan horse approach to smuggle themselves into this country. Both were believed to have been introduced with commodities not covered by the Plant Quarantine Act. The scolytid was unquestionably associated with logs of imported European burled elm. The finger of suspicion points to bones imported from South America as the agency which franked the white-fringed beetle by quarantine.

There are conflicting explanations as to how the Mediterranean fruitfly got into Florida. Fortunately it has been eradicated and is no longer with us. Information developed subsequent to its discovery in the Rio Grande Valley indicates the Mexican fruitfly had for many years made annual flights to the Valley. Its survival there as an economic pest only awaited the large scale citrus development of that area. Similarly it was inevitable that the pink bollworm once it was established in Mexico would eventually by-pass our quarantine stations and invade the contiguous cotton growing area of the United States. That all concerned were able to perfect a defense which for 20 years was to keep the pink bollworm from reaching our main cotton growing belt was in itself a remarkable achievement.

Besides successfully battling known plant pests which were subject of special quarantines, the Division of Foreign Plant Quarantines has during its existence divulged the presence of many unsuspected pests in agricultural commodities offered at quarantine. For example, *Conotrachelus aguacate* Barb. (from Mexican avocadoes in 1920) and *Epicaerus cognatus* Sharp (from Mexican potatoes in 1924) were unknown as plant pests before they were taken at quarantine. The assumption that the pineapple weevil was a pest peculiar to Jamaica underwent revision when plant quarantine inspectors found this insect in pineapples from Mexico. The discovery of *Epinotia opposita* Hein., originally recorded from Peru, but more recently found in green beans from Mexico, seems to lend credence to F. W. Webster's theory on diffusion of insects. This theory presumes that many accessions to our insect fauna have arrived from Central and South America through Mexico. The finding of *Gymnandrosoma* sp. in oranges from Mexico and *Leucinodes elegantalis* Gn. in tomatoes from Mexico, both Brazilian insects, might well be accepted as further evidence in support of Mr. Webster's contention. Then there is *Laspeyresia leguminis* Hein., also from beans, which has recently joined the ranks of named organisms. Besides these, numerous other partially named insects have been taken at quarantine from a long list of hosts and their status as pests is yet in the process of being appraised.

If, as some insist, the future is but the lengthening of the shadows of the past, then there remains a multitude of undiscovered pests with an unpredictable capacity for doing harm yet to be added to our manual of dangerous insects likely to be introduced into this country.

The task of safeguarding this country against foreign plant pests is as endless as the chore that confronted Danaus's daughters. Thrift, increased revenue, or political expediency may eventually bring us some relief from the burdensome taxes we now pay, but there are no party politics or economy minded finance committees among the pests that plague our agriculture. They never voluntarily reduce the toll they demand. Their take could easily be more. All we need to do is to relax our vigilance or weaken our defenses against the foreign pests that would invade our country.

These remarks feature just a few insects. Many others could be cited or emphasis as effectively shifted to foreign fungi, viruses, nematodes, or bacteria. They, too, menace our agriculture. It is a lack of time, not testimony, that limits this discussion.

With this, the defense rests. Are foreign plant quarantines worthwhile? We ask for no instructed verdict. Let our case be judged on its merits. Admittedly, much of the testimony we offer leans heavily on circumstantial evidence. Admittedly, too, the comparisons as used have not belittled our accomplishments. These devices, however, served not to mislead but to convince and convict. We hope, therefore, that in this instance comparisons will not prove odious and that the verdict reached will favor the defense.

O. D. DEPUTY,
U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine

Cotton States Branch
American Association of Economic Entomologists

Hotel Biltmore, Atlanta, Georgia
Proceedings of the Twenty-Second Annual Meeting

The twenty-second annual meeting of the Cotton States Branch of the American Association of Economic Entomologists was held in Atlanta, Georgia on February 4, 5, and 6, 1948. The meetings opened with an informal get-together on the evening of February 4. Well over 200 persons attended the paper reading sessions. A high degree of interest was maintained throughout the entire period.

Chairman Dwight Isely delivered a stimulating talk entitled "The Special Field of Service of Applied Entomology." This address was well received, and frequently praised thereafter by those in attendance.

President S. A. Rohwer of the Parent Organization was in attendance and contributed a great deal to the sessions of the executive committee. He gave a dynamic talk on constructive improvements planned for the association. In this talk he encouraged all members to contribute by offering suggestions for improvement.

Four other invitational papers were presented during the meetings. These were as follows: "The Present Status of the Pink Bollworm Problem in the United States and Mexico," presented by L. F. Curl; "The Present Status of Pink Bollworm Research Investigations," presented by R. W. Harned; "The Present Status of the White-Fringed Beetle Problem," presented by B. M. Gaddis; and "*Dacus dorsalis*, A Dangerous New Fruitfly Now in Hawaii," presented by C. P. Clausen. These papers were extremely informative, and provided up to date information pertaining to these three economic species.

The number of active members in the Cotton States Branch during the year 1947 was 402 which constituted an increase of 35 during the year. There are 80 contributing members, making a grand total of 482.

The sessions included the presentation of technical papers dealing with pests of sugarcane, stored grain, cotton, deciduous fruits, livestock, field crops, and those affecting man and domestic animals.

The arrangements for the 1948 meetings were excellent, and reflect credit upon the chairman of the local committee, Theodore Oser, and the following members of his committee: C. H. Alden, G. H. Bradley, Sam O. Hill, Kent S. Littig, Oliver I. Snapp, and Glenn H. Burnett.

One added special feature of the meetings was the excellent displays, motion pictures, and film strips arranged for the group at the Communicable Disease Center, by members of The United States Public Health Service.

The annual banquet was given this year in honor of the living entomologists who attended the first meeting of the Cotton Belt Entomologists, held in Atlanta, Georgia during May 1905. This included Gordon M. Bentley, Glenn W. Herrick, H. A. Morgan, and A. W. Morrill. Doctor Isely presided and introduced prominent people in attendance. Oliver I. Snapp paid due tribute to these early southern entomologists. The banquet was followed by the Entomologists dance.

BUSINESS PROCEEDINGS

The first business session was held at 11:30 A.M., Thursday, February 5. Chairman Dwight Isely presided. The following were present: Harry V. Ackerman, G. F. Adams, William E. Akin, C. H. Alden, John C. Alden, Norman Allen, J. L. Allgood, F. F. Arant, Phil Arey, F. J. Bartlett, Russell H. Beatie, I. J. Becnel, G. M. Bentley, Paul C. Betts, Jack M. Bickerton, C. J. Birgeaux, George H. Blake, Jr., Floyd F. Bondy, R. J. Both, L. H. Bowdoin, G. H. Bradley, James W. Brooks, W. G. Bruce, J. G. Brunton, W. H. Burnshide, J. Everett Bussart, Stewart L. Calhoun, Willis T. Campbell, Reuben Capelouto, O. L. Cartwright, Frank L. Chamberlin, C. P. Clausen, James H. Cochran, Raymond N. Cochran, K. L. Cockerham, C. C. Compton, Arthur Corry, S. Crawford, Jr., John T. Creighton, J. L. Crigler, L. F. Curl, R. H. F. Dade, G. W. R. Dvaidson, Geo. C. Decker, John J. Diem, Kelvin Dorward, W. E. Dove, W. A. Douglas, A. L. Dugas, E. W. Dunam, Minter Dupree, H. W. Dye, Hilton H. Earle, Jr., K. E. Ewing, T. C. Fancher, P. W. Fattig, Fred Fletcher, Henry Flick, Ernest H. Floyd, Herbert G. Ford, B. M. Gaddis, J. G. Gaines, R. C. Gaines, A. L. Galloway, J. W. Gibson, James E. Gillaspy, Edwin F. Glenn, Gene Grazer, C. Y. Haas, W. Preston Harden, R. W. Harned, R. C. Harden, C. S. Harris, Marvin M. Haschky, R. F. Hatcher, Ralph E. Heal, Charles F. Henderson, L. A. Hetrick, Maj. S. O. Hill, R. V. Hood, J. L. Horsfall, Dwight Isely, A. L. Jacobs, Calvin M. Jones, C. R. Jordan, Jr., Philip F. Keil, E. G. Kelsheimer, Walter M. Kulash, Horace W. Lee, J. H. Lee, George F. Leonard, Bernard A. Lepp, H. R. Lewis, Charles Lincoln, Kent S. Littig, Ralph R. Lloyd, Jr., Clay Lyle, M. S. Malone, S. Marcovitch, C. H. Matthews, J. Myron Maxwell, Paul Mayfield, William E. Merritt, W. H. Mecom, Joe E. Michael, Myron M. Milligan, Missbach, H. V. Mitchell, J. C. Moore, Wesley G. Morgan, Ralph L. Morris, G. F. Muller, W. E. McCauley, J. M. McGough, John I. McClurkin, Jr., Hoyt A. Nation, E. M. Naylor, Frank C. Nelson, W. C. Nettles, Leo D. Newsom, A. A. Nikitin, Jack Noble, R. W. Oliver, Miss Kellie O'Neill, Theodore Oser, C. M. Packard, C. R. Parancia, A. M. Phillips, N. Piesbergen, John G. Plowden, Harry D. Platt, R. C. Price, K. D. Quarterman, Clyde F. Rainwater, V. P. Rao, Frank Rapp, T. Walter Reed, E. H. Reese, Jr., W. J. Reid, P. J. Reno, G. G. Rohwer, S. A. Rohwer, W. Mercer Rowe, Jr., Jack C. Russell, J. G. Sanders, George L. Smith, Willie R. Smith, Oliver I. Snapp, L. M. Sparks, Jr., W. W. Stanley, C. J. Steinahauer, John E. Stevens, C. K. Stuart, George R. Swank, James Toffaleti, A. L. Taylor, C. H. Tidwell, William F. Turner, M. C. Van Horn, Eddie B. Vinson, Sam H. Walkup, Jr., Edward H. Warnhoff, Jr., Carl N. Watts, J. G. Watts, A. E. Weil, E. C. Westbrook, Jed Whit, W. H. White, D. A. Whitfield, George R. Williamson, Herbert M. William, John W. Wilson, Frank J. Woods, and John W. Zukel.

REPORT OF SECRETARY-TREASURER

Period of January 10, 1947–March 15, 1948

Total Funds Received	$901.61
Total Funds Expended	403.23

Funds being transferred to new Secretary

A. Savings Account Atlanta National Bank	126.63
B. Funds for Checking Account	371.75
Total	$498.38

FINAL BUSINESS SESSION

REPORT OF THE RESOLUTIONS COMMITTEE

1. Whereas, the members of the Cotton States Branch of the American Association of Economic Entomologists, in attendance at the 22nd annual meeting at Atlanta, Georgia on February 4–6, 1948 have enjoyed an interesting and profitable meeting. Therefore, Be It Resolved: That we hereby express our sincere appreciation to the following individuals, groups, and agencies who made this occasion a success.
   a. Chairman Theodore Oser and the members of the local arrangements committee for their efforts in our behalf.
   b. The manager and operational personnel of the Atlanta Biltmore Hotel for their many courtesies.
   c. Our Chairman, Vice-Chairman, and Secretary for so ably fulfilling their duties during the meeting and in making preparations therefor.
   d. Mr. S. A. Rohwer, President of the American Association of Economic Entomologists for his presence here representing the National Association and for his interesting and informative talk on the improvement of economic entomology.
   e. The Members of Industry and other companies which provided entertainment and refreshments.
   f. Mr. R. B. Brown for his services in so ably handling the matter of projection.
   g. The United States Public Health Service for their very excellent display at the Communicable Disease Center which was prepared for this group.
   h. The cooperation of the local press for their coverage of the meeting.
2. Whereas, the preponderance of papers read at this meeting have dealt with cotton insects.
   Therefore, Be It Resolved that investigators of fruit, vegetable, citrus and other insects be encouraged to participate more actively by presenting more papers at future meetings.
3. Whereas, the JOURNAL OF ECONOMIC ENTOMOLOGY has been an important and useful tool for the announcement of the program especially for the National meetings, and, whereas, in consequence of the considerable delay in the appearance of current issues of the JOURNAL, members of the association have no prior notice of the titles of papers which are to be presented, and whereas at some of the meetings there have been insufficient printed programs for those in attendance.
   Therefore, Be It Resolved: That the National Committee on Publications be advised that it is the desire of the Members of the Cotton States Branch to see that the publication of the JOURNAL be brought up to date; and furthermore, Be It Resolved, that the National Secretary be advised that it is the desire of the Members of the Cotton States Branch that an adequate number of printed programs be made available for those in attendance at the National Meetings, and that a copy of this program be mailed to each member of the Association in advance of the dates of the annual meeting.
4. Whereas, several of our beloved members were called to their eternal reward during the past year,
   Therefore, Be It Resolved: That we put in our permanent records this expression of our regret at the death of our friends and fellow workers.

W. G. BRUCE
J. G. WATTS
K. L. COCKERHAM

REPORT OF THE EXECUTIVE COMMITTEE

1. The Executive Committee Recommends that the Cotton States Branch request that the Parent Organization adopt a policy of submitting an agenda covering all points of business that are to be considered at the annual meetings, to each member of the association at least 15 days prior to the meeting, and that final association action on business be limited to those items appearing on the agenda.
2. The Executive Committee recommends that the Cotton States Branch adopt a policy of limiting the use of slides and other illustrative material to those that are legible in a room that will seat a minimum of 200 people, and that all slides be presented to a special committee at least one day prior to meeting, for approval.
3. The Executive Committee recommends that the Cotton States Branch request that the Parent Organization limit symposia or open forum phases of annual meeting to two in number, and that the remainder of the sessions be for purposes of presenting papers; in order to encourage young workers to appear on programs.
4. The Executive Committee recommends that the Cotton States Branch continue previously adopted policy of holding meetings one year in eastern territory, the next year in the Mississippi River territory, and the third year in western territory. Also that when such a schedule coincides with the meetings of the association of Southern Agricultural Workers that the meeting be held in conjunction with that organization.
5. The Executive Committee of The Cotton States Branch recommends that the Parent Organization in arranging a special membership and subscription rate for students in Universities and Colleges limit this rate to those students taking one half time load or more.
6. The Executive Committee recommends that the incoming executive committee give consideration to the desirability of changing the name of the Cotton States Branch to the Southern States Branch.

7. The Executive Committee recommends that the incoming secretary be instructed to write the officers of the Parent Organization indicating our gratification that the 1949 National Meetings will be held in Cotton States Branch territory, and offerings the services of the latter organization in making arrangements for the meetings.

DWIGHT ISELY
FLOYD F. BONDY
JOHN T. CREIGHTON
R. C. GAINES

REPORT OF THE NOMINATING COMMITTEE

The Committee on Nominations recommended the following for officers for the year 1948–49:

John T. Creighton, University of Florida, Gainesville, Florida, Chairman.
J. W. Ingram, Bureau of Entomology & Plant Quarantine, Houma, Louisiana, Vice-Chairman.
K. P. Ewing, Bureau of Entomology & Plant Quarantine, Waco, Texas, Secretary.

These officers were duly elected. The New Chairman was escorted to the place of honor by Past Chairmen Oliver I. Snapp, and R. W. Harned. He expressed appreciation for the honor, and outlined ways that the Cotton States Branch might broaden its influence in Economic Entomology, and urged the continued cooperation of the membership. The new Chairman then asked the new Secretary to come forward for formal presentation to those in attendance.

Final adjournment was proclaimed shortly thereafter.

JOHN T. CREIGHTON, *Secretary-Treasurer*